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PROPERTIES OF SOME AMERICAN KAOLINS AND A COMPARISON WITH ENGLISH CHINA CLAYS*

By T. A. Klinefelter and W. W. Meyer

Abstract

Nine American kaolins were studied. Chemical analyses were made and equivalent mineral compositions were calculated with the aid of petrographic examinations. Pyrometric cone equivalents, deflocculating characteristics, soluble-salt contents, percentages of material composed of particles less than 0.6 micron in diameter, and base-exchange capacities at p_H7 were determined. Transverse strengths of dried and variously heat-treated bars, made from mixtures of the clays with equal parts of potters' flint and shrinkages and apparent porosities of dried and progressively heat-treated all-clay specimens, were determined. Specimens of the dried and heated clays were examined for relative color, and linear thermal expansions of specimens heated to various temperatures were determined. The nine clays were divided into three groups and their properties compared with those of fifteen English china clays previously studied. Simulation of essential properties of the English china clays was accomplished in supplementary experiments by adding fluxes to American kaolins or kaolin blends.

I. Introduction

China clays or kaolins are an integral part of whiteware body mixtures. While American kaolins are available in ample quantity, the whiteware industry continues to import a large tonnage of English china clay. There are sufficient differences in properties of the two groups of clays to cause a manufacturer hesitancy in substituting the domestic for the foreign material because such substitutions, made without consideration of these differences, have been known to result in considerable losses. Strangely, the difficulties encountered can be attributed usually to the greater purity of the American clays.

Note: In this paper the choice of the terms "kaolin" and "china clay" is based upon commonly accepted usage.

This investigation had as its object a study of the properties of American kaolins and the determination of reasons for differences in properties of American kaolins and English china clays[1] which affect the substitution of the former for the latter. It was thought that the data obtained would make possible the fabrication of mixtures of certain of the American clays and suitable fluxes which could be readily substituted for English china clays in whiteware body mixtures.

II. Materials and Methods

Nine American kaolins, designated R to Z, inclusive, were supplied by domestic producers. Clay R was a primary kaolin from Delaware; S, a North Carolina primary kaolin; T, a South Carolina secondary kaolin; U, V, and W, secondary kaolins from Georgia; and X, Y, and Z, secondary clays from Florida. All of the clays had been washed except V, which had been air-separated.

The same tests and procedures were used as in the study of English clays with the following exceptions. The only routine tests made on clays with admixtures were determinations of transverse strengths of specimens containing equal proportions by weight of flint and clay in the dried and variously heat-treated conditions. Deflocculation tests were made by observation of the settling behavior of 10% suspensions of clay in water, to which had been added ammonium hydroxide in progressive ratios of NH_3 to dry clay of from 1:1000 to 1:273. The final supercentrifuge separation was at a bowl-speed of 20,000 instead of 18,000 revolutions per minute, yielding an overflow product with an estimated maximum particle diameter of 0.6 micron. The electrodialysis, in preparation for the determination of base-exchange capacities at p_H7,[2] required from 12 to 72 hours, and the final current through the cell was in no case more than 0.04 ampere.

III. Properties of American Kaolins

As the investigation of American kaolins pro-

* Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

Received January 4, 1935.

[1] The results of a study of the English china clays have been published. See T. A. Klinefelter, W. W. Meyer, and E. J. Vachuska, "Some Properties of English China Clays," *Jour. Amer. Ceram. Soc.*, **16** [6] 269–76 (1933).

[2] The phrase "base-exchange capacity at p_H7" will be used in this paper in place of "total base-exchange capacity" since, in view of recent writings, it is apparent that the latter term is ambiguous. See S. Mattson, *Soil. Sci.*, **34**, 459 (1932); *Ceram. Abs.*, **14** [2] 54 (1935); and W. W. Meyer, "Colloidal Nature and Related Properties of Clays," *Nat. Bur. Stand. Jour. Research*, **13** [2] 245 (1934); R.P. 706; also *Ceram. Abs.*, **13** [11] 302 (1934).

gressed, it became evident that with respect to many of the properties these clays could be divided into three groups: (1) those of primary origin, clays R and S; (2) certain of the secondary clays, X and Y; and (3) the remainder of those of secondary origin, clays T, U, V, W, and Z.

In comparing the kaolins with each other and with the English china clays, it was found convenient to consider each of these groups separately.

TABLE I

COMPOSITIONS OF AMERICAN KAOLINS[a]

Group	Clay	Ignition loss (%)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	TiO_2 + ZrO_2 (%)	CaO (%)	MgO (%)	K_2O (%)	Na_2O (%)	Total (%)	Kaolinite[b] (%)	Free[b] silica (%)	Mica[b] and feldspar (%)	RO_2/R_2O_3[c] Ratio of < 0.6μ fraction
I	R	11.6	49.2	34.9	2.0	0.2	0.0	Tr.	1.8	0.2	99.9	82.3	2.8	12.5	2.0
	S	13.2	47.9	37.4	0.4	0.0	0.1	Tr.	1.1	0.1	100.2	91.2	0.9	7.3	1.9
II	X	13.7	46.3	37.7	0.8	0.5	0.5	Tr.	0.2	0.0	99.7	91.2	2.0	4.5[d]	1.9
	Y	13.6	46.6	37.6	0.7	0.5	0.7	0.0	0.5	0.0	100.2	88.2	2.3	7.3[d]	1.9
III	T	13.8	45.2	39.0	0.3	1.5	Tr.	0.0	0.2	0.0	100.0	95.7		2.0[d]	1.7
	U	13.7	45.7	38.7	0.3	1.4	0.2	Tr.	0.0	Tr.	100.0	96.9	0.1	1.3	2.0
	V	13.9	45.1	39.1	0.2	1.7	0.1	0.0	0.1	Tr.	100.2	96.5		1.3[d]	1.9
	W	13.5	45.5	39.0	0.4	1.6	0.1	0.0	0.1	0.0	100.2	97.4		0.7[d]	2.0
	Z	13.8	46.9	38.5	0.4	0.2	Tr.	0.0	0.2	0.0	100.0	95.8	1.7	1.5[d]	1.9
Av. group I		12.4	48.6	36.2	1.2	0.1	0.1	Tr.	1.5	0.2	100.3	86.8	1.9	9.9	1.95
Av. group II		13.7	46.5	37.7	0.8	0.5	0.6	Tr.	0.4	0.0	100.2	89.7	2.2	5.9	1.9
Av. group III		13.7	45.7	38.9	0.3	1.3	0.1	Tr.	0.1	Tr.	100.1	96.5	0.4	1.4	1.9
Av. 15 English china clays		12.7	46.6	37.7	0.7	0.2	0.1	0.2	1.4	0.2	99.8	83.8	2.1	12.3[d]	2.2[e]

[a] Analyses by J. F. Klekotka.
[b] Calculated from results of chemical and petrographic analyses, the latter by H. Insley, except the English china clays, which were examined by G. R. Shelton.
[c] Analyses of American kaolin fractions by E. H. Hamilton.
[d] No feldspar discernible under microscope.
[e] Analyses of < 0.7 micron material by W. W. Meyer.

(1) Chemical and Mineral Compositions

The chemical and calculated equivalent mineral compositions of the nine American kaolins, the average of each of the three groups of American clays, and the average of fifteen English china clays are given in Table I. The $RO_2:R_2O_3$ ratios of those fractions of the clays composed of particles less than 0.6 micron in diameter are included (less than 0.7 micron in diameter in the case of the English china clay average).

The following data are from a report by H. Insley, who examined the American kaolins petrographically.

Clay R: Besides kaolinite, contains considerable potash feldspar, muscovite, biotite, hematite (or goethite), and a small amount of quartz.

Clay S: Principal constituents are (1) a platy mineral occurring usually as vermicular aggregates, with a medium birefringence and mean refractive index of about 1.56; one of the kaolin minerals, perhaps kaolinite and (2) thin, fairly broad plates with irregular edges. The plates show an extremely weak, uniaxial, negative interference figure. Individual plates vary considerably in index, but the mean is about 1.565. Some of these plates may be muscovite, but the majority are a kaolin or clay mineral, possibly halloysite, or aggregates of colloidal clay particles.

Subordinate constituents are iron oxide, opaque grains, and feldspar (plagioclase).

This clay seems to contain some gouge material or weathered volcanic ash. Some particles have the shape of ash particles.

Clay T: A fine-grained clay composed of (1) vermicular aggregates of plates like clay S(1), (2) thin, broad plates like clay S(2), (3) aggregates of minute particles or needle-like crystals with very high refractive index and high birefringence, probably rutile, and (4) a few small opaque particles. No feldspar could be observed.

Clay U: A fine-grained clay having constituents like clay T(1), T(2), and T(3), a trace of feldspar, and no opaque material.

Clay V: Coarser-grained than U, and composed largely of platy grains like clay S(2); there are fewer of the vermicular aggregates; grains like clay T(3) are present and also a few opaque particles.

Clay W: A very fine-grained clay, composed of vermicular aggregates of plates, with fewer of the large platy crystals; aggregates like clay T(3) are present; very little opaque material.

Clay X: Composed largely of vermicular aggregates and uniaxial, negative plates; contains a small amount of quartz and occasionally a broad plate of muscovite; also a very small number of aggregates like clay T(3).

Clay Y: Composed largely of vermicular aggregates with a refractive index of about 1.56; a few large irregular plates; also a small amount of material with irregular, elongated outline, low refractive index, and medium birefringence; these are possibly shreds of volcanic glass rather thoroughly altered to montmorillonite; a small amount of quartz is present and a very little material like clay T(3).

Clay Z: A mixture of vermicular aggregates and platy grains, with a small amount of the low refractive-index material like that observed in clay V; contains a trace of quartz and a small amount of material like clay T(3).

(2) Pyrometric Cone Equivalents

The pyrometric cone equivalent[3] of clay R was 33 to 34 and of clay Y, 34. Clays S and X were pyrometrically equivalent to cones 34 to 35, and clays T, U, V, W, and Z were pyrometrically equivalent to cone 35. The average pyrometric cone equivalent of fifteen English china clays was 34.

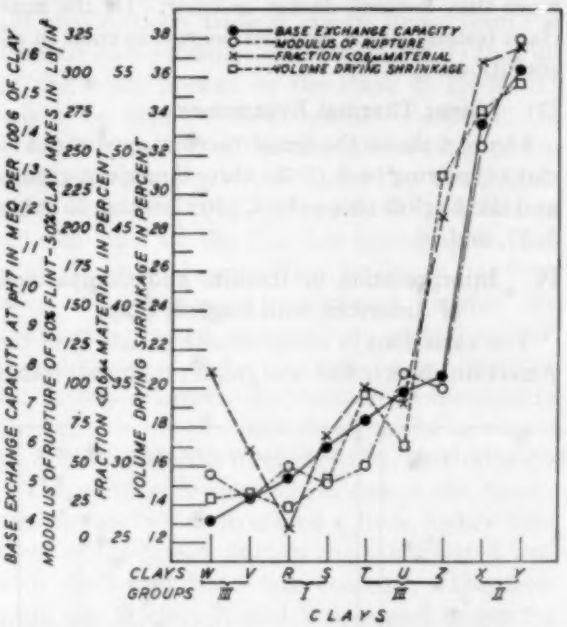
BASE EXCHANGE CAPACITY AT pH7 IN MEQ PER 100 G OF CLAY
MODULUS OF RUPTURE OF 50% FLINT-50% CLAY MIXES IN LB/IN²
FRACTION <0.6μ MATERIAL IN PERCENT
VOLUME DRYING SHRINKAGE IN PERCENT
BASE EXCHANGE CAPACITY
MODULUS OF RUPTURE
FRACTION <0.6μ MATERIAL
VOLUME DRYING SHRINKAGE
CLAYS W V R S T U Z X Y
GROUPS III I III II
CLAYS

FIG. 1.—Base-exchange capacities at p_H7, dry transverse strengths, percentages of material less than 0.6 micron in diameter, and volume drying shrinkages of nine American kaolins.

(3) Deflocculation, Soluble Salts, Colloidal Material, and Base-Exchange Capacities

The ratios of NH_3 to dry clay, which caused maximum deflocculation of 10% suspensions of the kaolins, varied from 1:300 to 1:600. The soluble-salt contents of the kaolins, as received from their producers, varied from 0.04 to 0.17%. The percentages of material less than 0.6 micron in diameter and the base-exchange capacities of the clays at p_H7 are shown in Fig. 1. The averages of the former are 29% for group I, 57% for group II, and 36% for group III, while the average amount of material smaller than 0.7 micron in diameter present in fifteen English china clays was found to be 32%. The averages of the base-exchange capacities (at p_H7) of the American clays were 5.6 millequivalents of bases per 100 grams of clay for group I, 15.0 for group II, and 6.1 for group III, while the fifteen English clays averaged 4.9.

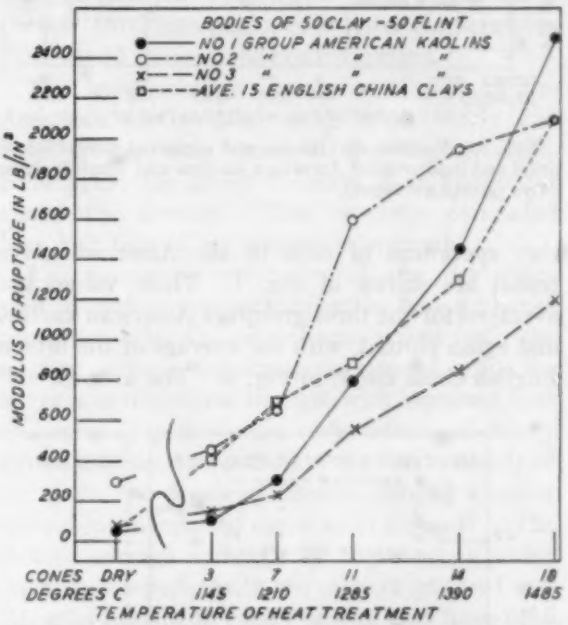
BODIES OF 50 CLAY - 50 FLINT
NO 1 GROUP AMERICAN KAOLINS
NO 2 " " "
NO 3 " " "
AVE. 15 ENGLISH CHINA CLAYS
MODULUS OF RUPTURE IN LB/IN²
CONES DRY 3 7 11 14 18
DEGREES C 1145 1210 1285 1390 1485
TEMPERATURE OF HEAT TREATMENT

FIG. 2.—Transverse strengths (expressed as moduli of rupture) of dried and heat-treated American kaolins and English china clays mixed with equal amounts of flint (group averages).

(4) Transverse Strengths

The transverse-strength values of dry specimens of each of the American clays mixed with equal parts of potters' flint are shown in Fig. 1.

Similar values for the three American clay groups and for the fifteen English clays are shown in Fig. 2. This figure shows also the average transverse-strength values of these groups of clay-flint mixtures after heat treatments to cones 3, 7, 11, 14, and 18.

(5) Shrinkages and Apparent Porosities

The volume shrinkages during drying of the all-

[3] Determined by W. L. Pendergast, Refractories Section, National Bureau of Standards.

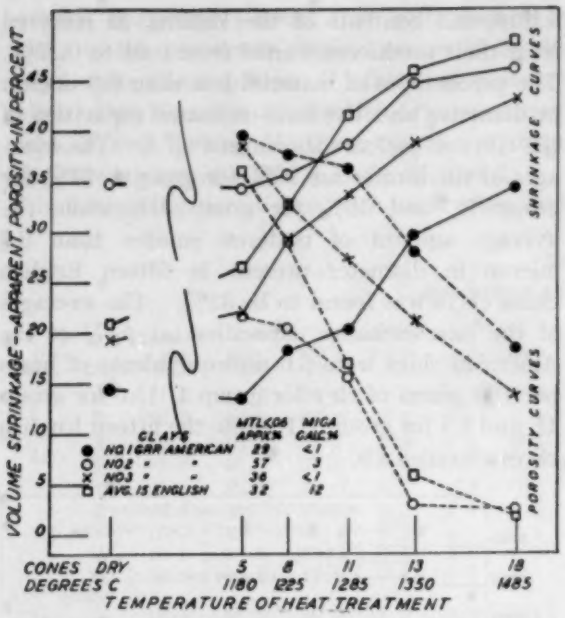

FIG. 3.—Volume shrinkages and apparent porosities of dried and heat-treated American kaolins and English china clays (group averages).

clay specimens of each of the American clays tested are shown in Fig. 1. These values are averaged for the three groups of American kaolins and again plotted, with the average of the fifteen English china clays, in Fig. 3. The average volume shrinkages of these four groups of clays, resulting from heat treatments to cones 5, 8, 11, 13, and 16, also are shown in Fig. 3. In addition, this figure shows the average percentage apparent porosities of all-clay specimens of the three groups of American clays, and of the English clays, in the dried condition and after heat treatments to cones 5, 8, 11, 13, and 16.

(6) Colors

Clays S and Z were as nearly white in the dried and variously heat-treated conditions as the better English clays, while clays T, U, V, and W were slightly darker. Clays X and Y were in this latter class in the dry condition and after heating to cones 5, 8, and 11, but when heated to cone 13 or more they became darker in color. Of the nine clays tested, clay R was the poorest in color in all conditions.

(7) Linear Thermal Expansions

Figure 4 shows the linear thermal expansions of clays typifying each of the three American groups and the English china clays, after heating to cones 5, 11, and 16.

IV. Interpretation of Results and Comparison of American with English Clays

The variations in compositions (Table I) of the American clays tested was greater than that found

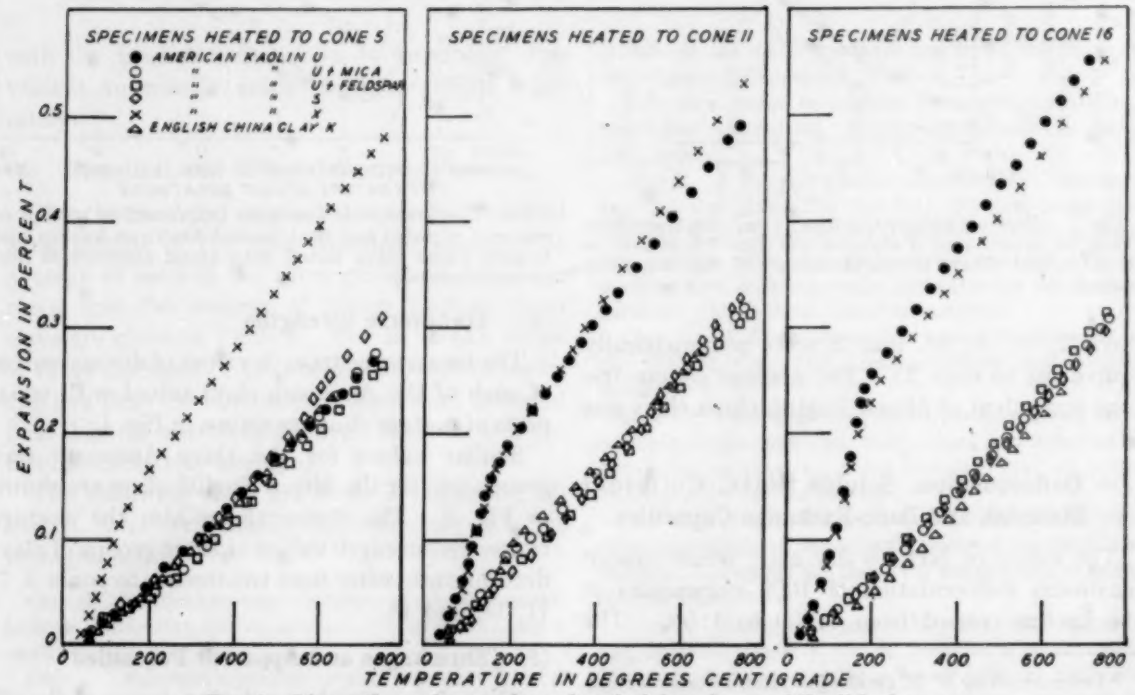

FIG. 4.—Linear thermal expansions of typical American and English clays.

in the English clays. The American clays of group I, probably because of their primary origin, resembled the English clays more closely than did the clays of groups II and III. The iron content of clay R, however, was so great that its color was much inferior to that of any other clay tested. The most effective differences in compositions of the foreign and domestic clays were the much greater amounts of fluxing constituents and smaller amounts of titanium in the former as compared with most of the latter. The calculated percentages of kaolinite in the American clays, especially those in group III, were high compared with those in the English clays.

The percentages of fluxing minerals given in Table I are theoretical, being based on the chemical compositions, while it can be shown from the data on base-exchange capacities (Fig. 1) that all of the bases present in the clays of group III might be held in the adsorbed condition. In group I, 10 to 25% of the bases present might be so held, in group II 45 to 65%, and in the English china clays 5 to 20%. This possibility is further substantiated by the fact that petrographic data show the clays of group III to be almost free from mica and feldspar. Discrepancies between the calculated mineral compositions and those obtained by petrographic analyses can be accounted for in this manner. Furthermore, variations in the activities of the basic fluxes might be caused by differences in the forms in which they occur.

The pyrometric cone equivalents of the American kaolins, which averaged a little higher than those of the fifteen English clays, correlated well with their calculated flux contents. The finer grain size of clays X and Y appeared to exert a slight influence. There seems to be a similar rough relationship between pyrometric cone equivalent and flux content and grain size of the English clays.

The amounts of soluble salts in the American kaolins varied to about the same extent as those found in the English china clays and in neither case seemed to correlate with any other property. The amounts of reagent necessary to cause maximum deflocculation of the kaolins, as in the case of the English china clays, also correlated with no other property.

The percentages of material less than 0.6 micron in diameter in the American clays varied more widely and were greater than those of material less than 0.7 micron in diameter in the English clays. The clays of group II, however, which contained the largest amounts of this fine material, could hardly be considered to be of true china clay type. They might be more correctly classed as "ball kaolins." The percentages of material less than 0.6 micron in diameter in the American clays were found to correlate roughly (with the exception of clay W) with the base-exchange capacities at $p_H 7$, the transverse strengths when dry, and especially the volume shrinkages during drying (Fig. 1).

The differences in $RO_2:R_2O_3$ ratios in the fine fractions of the English and domestic clays possibly are due to differences in climatic conditions[4] during their formation. The higher ratios of the fine fractions in the English clays might cause them to enter into reactions at lower temperatures than would those in the domestic clays.

The base-exchange capacities at $p_H 7$ of the American kaolins also varied more widely and were greater than those of the English clays. Here again the group II clays gave values far above the average. This property correlated best with that of dry transverse strength.

The transverse strengths of the dry clays seemed to depend mostly upon the base-exchange capacities (Fig. 1) and to some extent upon the amount of fine-grained material present, while the increase in transverse strength with increased heat treatment (Fig. 2) seemed to be influenced chiefly by the amount and nature of the flux contents of the clays, the degree of fineness playing a minor rôle except in extreme cases, as in group II. The greater average strength of the English china clays, as compared with the clays of groups I and III, after heating to cone 7 or less, may have been due to their content of magnesium, which might be present as part of the clay or fluxing minerals, in an adsorbed condition, or both. None of these American kaolins contains more than traces of this substance and the calcium contents are about the same as in the English clays. On the other hand, the group II clays contain considerably more calcium, but their much greater fineness prevents any comparison on the basis of fluxes alone. The effects of magnesium carbonate and calcium carbonate as body fluxes were investigated some time ago[5] and the conclusions as to comparative fluxing actions seem to agree with

[4] See references in footnote 2.

[5] F. H. Riddle and W. W. McDanel, "Some Types of Porcelain," *Jour. Amer. Ceram. Soc.*, 1, 620 (1918).

those of this study. Another possible explanation of this greater transverse strength of the English clays might be furnished by the fact that in most of these clays the fluxes are concentrated in the finer-grained material, while in the American clays the fluxes are concentrated in the coarser fraction.

The great increase in strength of the group II clays between cones 7 and 11 (Fig. 2) was very likely a result of their high percentage of fine-grained material, together with the considerable amount of mica, iron, and adsorbed fluxes. The effect of the flux contents of the group I clays is readily seen in the average transverse strength values for the clay-flint mixtures. Clay R is much stronger than clay S in all cases, due to its greater content of iron and other fluxes. The effect of the lack of fluxes in the group III clays also is apparent from Fig. 2.

The chief factors governing shrinkage during drying (Figs. 1 and 3) seem to be the amounts of fine material present and the base-exchange capacities, while in the variously heat-treated conditions the shrinkages and porosities (Fig. 3) apparently are influenced by the amounts and natures of the fluxing constituents as well as the amounts of fine-grained material in the clays. The effect of the mica and magnesium contents on these properties of the English china clays is particularly noticeable. Feldspar seems to exert less influence in this respect than mica, as is evident by a comparison of the curves for clays of group I and those for the English china clays. The group I clays also contain less fine material, and while the fluxes are concentrated in the fine fraction of the English clays, the reverse is true of the clays of group I.

With the exception of clay R, those American kaolins which were inferior to the English china clays in color after heat treatment owe their inferiority chiefly to a greater titanium content. This fact is particularly true of the Georgia and South Carolina clays. The colors of the heat-treated clays, S and Z, are equal or superior to that of the best English clay.

Thermal-expansion data indicate that the American kaolins of group I either did not yield cristobalite on heat treatment or else it was dissolved in the glass as it was formed. These two kaolins had thermal-expansion properties similar to those of the English clays. Microscopic examination of clay S heated to cone 16 showed only mullite and glass to be present. The clays of group II showed formation of cristobalite by the time heat treatment had reached cone 5. This early formation of cristobalite was probably due, in part, to the large amount of fine material present in these clays and possibly in part to a catalytic action of the adsorbed bases. All of the clays of group III formed cristobalite during heat treatment, three of them (T, U, and W) between cones 5 and 11, and the other two between cones 11 and 16.

V. Simulation of English China Clay Properties

One of the commonest commercial practices in substituting American for English china clays has been to use a mixture of two or more American clays from different groups, such as I and II. It is possible in this way to maintain the color and drying shrinkage desired, but the properties of the resulting body in the heated state often fail to duplicate those of the original body. The difference is due primarily to the smaller content of fluxing materials in the American kaolins.

TABLE II
MIXTURES SIMULATING ENGLISH CHINA CLAYS AND THEIR PROPERTIES

Mixture	1 (%)	2 (%)	3 (%)	4 (%)	English china clay (%)
Clay S	70.0	61.8	93.8		
Clay U				87.5	
Clay X	30.0	31.0			
Buckingham feldspar		7.2	6.2	12.5	
Magnesium carbonate (added)		0.4	0.4	0.4	
Fine fraction (approx.)	37	35	27	33	32
Total fluxes	8.7	12.3	12.3	12.3	12.3
	Percentage volume shrinkage				
Drying	20				21
Heating to (°C)					
1200	23	29	27	40	35
1300	28	39	30	44	42
1400	38	43	40	45	46
	Percentage apparent porosity				
1200	30	22	27	16	23
1300	25	11	20	8	13
1400	12	2	13	4	4
	Percentage thermal expansion, 20 to 750°C				
1300	0.45	0.31	0.31	0.31	0.29

The effect of mica additions on the thermal expansion of a secondary American kaolin has been investigated[6] and found to be beneficial. Mica, however, is not commonly used as a ceramic

[6] R. A. Heindl, W. L. Pendergast, and L. E. Mong, "Kaolins: Effect of Firing Temperatures on Some of Their Physical Properties," *Bur. Stand. Jour. Research*, **8**, 199 (1932); R.P. 410; *Ceram. Abs.*, **11** [6] 387 (1932).

flux, while feldspar and other fluxes are. As a preliminary study, specimens of 87.5% clay U and 12.5% Buckingham feldspar[7] and muscovite mica, respectively, were heated to cones 5, 11, and 16, and their thermal expansion characteristics were determined. The mineral composition of the clay-feldspar mixture was calculated to simulate that of the average English china clay. The curves in Fig. 4 show that feldspar is a little more

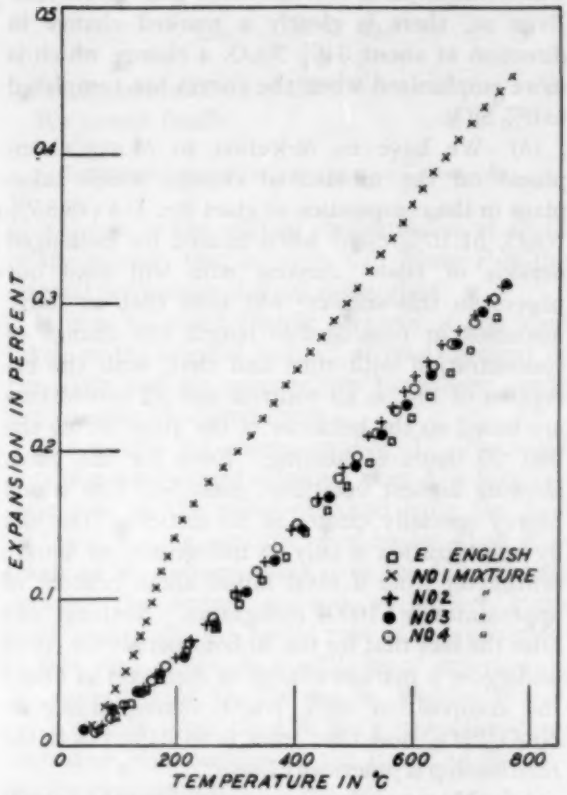

FIG. 5.—Linear thermal expansions of English china clay and simulating mixtures embodying American kaolins.

effective than mica up to cone 11, while mica seems slightly more effective at cone 16. Both fluxes were capable of eliminating the cristobalite expansion.

Further tests were made, using the compositions given in Table II.

The proportions of the clays in mixtures 1 and 2 were based on the drying shrinkages of the clays used as compared with those of the English china clays, while the amounts of feldspar and magnesium carbonate were in each case (except for mixture 1) calculated to give the mixture approximately the average mineral composition of the English clays. Specimens of each composition were heated to 1200°C, 1300°C, and 1400°C and their volume shrinkages and apparent porosities were determined. Linear thermal expansions of samples heated to 1300°C were determined and also the volume drying shrinkage of mixture 1. The data are given in Table II and Fig. 5. The results indicate that mixtures 2 and 4 had properties sufficiently like those of the English china clay to make their substitution for the latter seem practicable. The color of mixture 2 was slightly darker than that of the better English clays. It is probable that similar results could be obtained by using clay Y instead of X in mixture 2 and kaolins T, V, W, or Z in place of U in mixture 4.

[7] Calculated theoretical feldspar content about 92%.

VI. Summary

The essential properties in which the English china clays and most of the comparable American clays differ are (1) refractoriness, (2) color, (3) strength after low-temperature heat treatment (*i.e.*, less than cone 7), (4) linear thermal expansion, and (5) shrinkage and porosity after heat treatment at all temperatures. These differences usually can be traced primarily to fundamental differences in equivalent mineral compositions and secondarily to differences in the amount of fine-grained material present.

Basing the computations on the mineral compositions and drying properties of the English and American clays, it is possible to obtain mixtures of one or more of the latter with certain fluxes, such as feldspar and magnesium carbonate, which have properties sufficiently like those of the English clays as to make substitution seem practicable. The investigation of such substitutions is being continued.

Acknowledgments

The data on shrinkage and porosity (Fig. 4) were collected by Carl H. Rapp, coöperative fellow, Columbus Branch, National Bureau of Standards and Engineering Experiment Station, Ohio State University. Acknowledgment is due the following firms for their coöperation in furnishing the American clay samples used in this investigation: Harris Clay Co., Vanderbilt Kaolin Co., Edgar Plastic Kaolin Co., Moore & Munger, Golding Sons Co., and United Clay Mines Corporation.

VOLATILIZATION AND THE CONSTITUTION OF GLASS*

A Reply to a Recent Criticism of G. W. Morey

By E. Preston and W. E. S. Turner

I. Introduction

It is not our present purpose to discuss the general question of the constitution of glass. Our object is to reply to certain criticisms which G. W. Morey[1] has made concerning our interpretation of the results we have obtained during the past three years from investigations on the volatilization which occurs at temperatures between 1000° and 1400° from soda-silica glasses. Morey's specific criticisms are (1) that the curves relating the thermal composition to the amount volatilized in different periods in time are drawn arbitrarily, that to represent the last three points in each curve by straight lines intersecting the zero axis at the composition of sodium disilicate is without justification, and that the amount of change of concentration by volatilization from glass No. 114 completely vitiates all the conclusions drawn from the figure, (2) that we have achieved classification of the $Na_2O{\cdot}SiO_2$ glasses into two groups by applying a different method of calculation to each group, and (3) that the vapor pressure of any component from such a continuous series of liquids can not be discontinuous, but must be a continuous function of the composition.

Let us see how far these criticisms can be upheld (and we hope that the reader interested in this subject may have the patience to examine our data).

II. Method of Plotting[1a]

(*a*) We have only two objections to offer to Morey's replotting of our results (Fig. 4), namely, that the observations corresponding to the composition 11.83% Na_2O (glass No. P127) are not marked by circles and although the replotted curves are carried to that point, the reader may regard the extreme ends of the curves as merely arbitrary appendages rather than as corresponding to actual measurements; and further, we do not know why Morey should not complete the curves, as we have done, by convergence to the zero point of the diagram, since we have shown, both indirectly and directly, that at 1400° the volatility of silica is practically nil.

Had Morey completed the curves as stated, they would but have corresponded to similar curves we had ourselves prepared initially. As he has presented them, they convey to the reader the impression of a continuously varying vapor pressure with concentration of Na_2O in the glass under test. Even so, there is clearly a marked change in direction at about 34% Na_2O, a change which is more emphasized when the curves are completed to 0% SiO_2.

(*b*) We have no objection to Morey's emphasis on the substantial change which takes place in the composition of glass No. 114 (48.85% Na_2O, 51.15% SiO_2) when heated for prolonged periods of time. Anyone who will read our papers on this subject[2] will note that we have discussed at considerable length the change of concentration with time and that, with the exception of Fig. 4, all controls and all conclusions are based on the behavior of the glass during the first 20 hours of heating. Even for the glass, showing highest volatility, glass No. 114, which Morey specially quotes in his criticism, the loss by volatilization is only 48 milligrams per square centimeter from a total initial alkali content of approximately 1600 milligrams. Nothing can alter the fact that for the 20-hour period the curve undergoes a marked change of direction at about the composition 34% Na_2O, corresponding to $Na_2O{\cdot}2SiO_2$, and that from 0 to 34% Na_2O the relationship is practically linear.

(*c*) Morey makes no reference to the results for temperatures at 1300° and 1100°, at which the changes in concentration, even for glass No. 114, are small. The graphs for the results at these temperatures still more strongly emphasize the change in the character of the volatilization which takes place in the region of 34% Na_2O.

(*d*) There is no reference in Morey's paper to our studies of the K_2O–SiO_2 and the Li_2O–SiO_2 glasses. The curves for the 20-hour period of heating in the last-named system show two sharp changes of direction, namely, at $Li_2O{\cdot}2SiO_2$ and $Li_2O{\cdot}SiO_2$, and no form of continuous curve could fit the experimental data.

(*e*) If the simple graphical representation of our results for the $Na_2O{\cdot}SiO_2$ system(Morey, Fig. 4)

* Received February 4, 1935.

[1(a)] G. W. Morey, "Constitution of Glass," *Jour. Amer. Ceram. Soc.*, **17** [11] 315–28 (1934).

[1(b)] See Morey's Figs. 4 and 5, *ibid.*, p. 320.

[2] See footnotes 3, 4, and 6.

is somewhat arbitrary and liable to lead to misconception, there is another way of approaching the problem of comparing the rate of volatility at the very beginning of the heating period, or, mathematically, zero time. It is the initial rate of loss which is of the greatest importance when studying the volatilization-concentration relationship, and we have, accordingly, calculated the initial rate of volatilization at zero time, from the equation

$$\text{Log}\,\frac{A-2x}{A} = -kt$$

for each glass heated at 1400°.

We obtain finally

$$\text{Initial rate of loss per unit area} = \frac{dr}{dt_0} = -kn_0$$

in which n_0 is the original concentration of alkali in the surface, that is, $n_0 = CP$, where P is the original percentage of Na_2O in the glass.

It is to be noted that in this case A has been taken as the original amount of Na_2O present in the glass and no assumptions have been made as to its possible distribution.

The results are shown on Fig. 1. The solid dots represent values obtained when K is taken in each case as the value obtained from the first 20 hours heating, and the open circles when K is taken as an average value over the full heating period. The former method we believe gives more accurately the initial rate of volatilization at zero time under our conditions of experiment. We do not think that it can be doubted that a great change takes place in the evaporation-concentration relationships in the region of the disilicate composition.

III. The Application of the Equation $\text{Log}\,\frac{A-2x}{A}$

Regarding Morey's discussion of the graphs for the $Na_2O{\cdot}SiO_2$ series plotted to show the progress of time on the volatilization according to the formula

$$\text{Log}\,\frac{A-2x}{A} = -kt$$

which was developed on the assumption of a straight-line concentration gradient, we believe that, unintentionally, we have been misrepresented and would recommend a more careful perusal of the first paragraph of our original publication.[3] It is precisely because two families of curves are obtained that we believe our assumptions to be justified, *viz.*, that in compositions up to 34% Na_2O, A must be regarded as the total sodium oxide present in the mixture (presumably $Na_2O{\cdot}2SiO_2$ and SiO_2) and beyond this percentage A must be regarded as the total Na_2O present as the metasilicate in the supposed mixture of $Na_2O{\cdot}SiO_2$ and $Na_2O{\cdot}2SiO_2$.

When this is done, two families of curves are obtained having approximately the same value of K for the graphs of each group, *viz.*, approximately

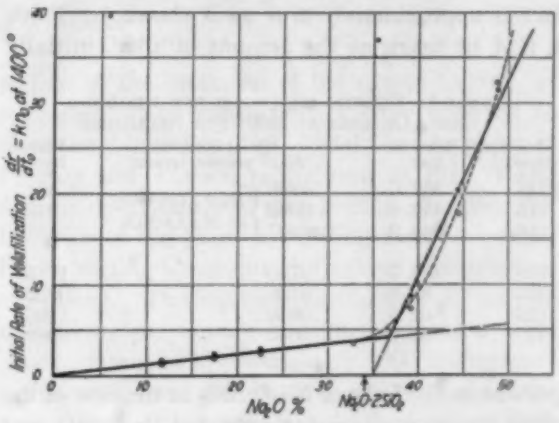

FIG. 1.

100 for the $Na_2O{\cdot}2SiO_2$–SiO_2 mixtures and approximately 700 for the metasilicate-disilicate mixtures. The connection between Morey's Figs. 4 and 6 (our original 4 and 7) is much closer than is at first apparent. In our recent paper on the $Li_2O{\cdot}SiO_2$ series[4] this matter is discussed more fully. Theoretically, the time equation should give a straight-line graph. It will be noted that it does not do so in the case of glasses which we have assumed to consist of $Na_2O{\cdot}SiO_2$–$Na_2O{\cdot}2SiO_2$, unless the volatilization is regarded as taking place from the metasilicate. For as the concentration of Na_2O in the glass surface decreases there will be then a progressive change in the ratios of the amounts of the two silicates present such that the mixture, or mutual solution, gradually moves toward 100% $Na_2O{\cdot}2SiO_2$. This point

[3] Eric Preston and W. E. S. Turner, "The Volatilization and Vapor Tension at High Temperatures of the Sodium Silicate-Silica Glasses," *Jour. Soc. Glass Tech.*, 16, 331 (1932) (p. 349).

[4] Eric Preston and W. E. S. Turner, "Volatilization of Lithium Oxide at High Temperatures from Lithium Oxide-Silica Glasses," *Jour. Soc. Glass Tech.* (*Trans.*), 18, 143 (1934).

is also further discussed in the lithium-oxide paper.

Further consideration of the equation

$$\text{Log}\,\frac{A-2x}{A} = -kt$$

leads to the conclusion that the time to reach any given fractional loss A/f equals

$$t_f = \frac{1}{2K}\log\left(1-\frac{2}{f}\right)$$

or "that the time required to reach any given fractional loss will be the same for similar glasses, at the same temperature, and under identical conditions." As to the soda-silica glasses, this fact is approximately true as is shown by Table I, if A be taken as the amount of alkali initially

TABLE I. FRACTIONAL LOSSES FOR THE SODA-SILICA GLASSES AT 1400° FOR 100 HOURS

Glass	Total loss (mg.)	Initial quantity Na_2O present (gram)		Fractional loss
P114	597.0	1.4890	Na_2O present as $Na_2O\cdot SiO_2$	0.401
115	413.0	1.0002		.413
116A	244.0	0.6407		.381
118	108.7	.9750		.1115
123	84.0	.9130		.0922
125	62.5	.5650		.1106
127	36.0	.3640		.0989

present in the form of $Na_2O\cdot SiO_2$ in the case of the three glasses presumed to consist of $Na_2O\cdot SiO_2$ and $Na_2O\cdot 2SiO_2$. Then it is seen that in each group the fractional loss is approximately constant for glasses of the same type.

IV. Vapor Pressure Continuous or Discontinuous Function of Composition

Morey's statement (the italics are ours) that "we can be assured that the vapor pressure of any component from such a *continuous series of liquids* can not be a discontinuous, but must be a continuous function of the composition" seems to us to entirely beg the question for it implicitly contains the point of view which Morey is trying to prove.

Surely, if in a system of components x and y we have a change over from

Liquid A + liquid B to liquid B + liquid C

we should not expect the vapor pressure of component x to be a continuous function over the whole range of compositions.

It is unwise at this stage of our knowledge to enter upon any dogmatic views of what we may describe as the "fine" structure of glass, but we believe that, contrary to Morey's view of the random network hypothesis, recent results of X-ray measurements on glasses and liquids tend to support the view of orderly molecular arrangement, in groups of very small dimensions, these tiny groups being certainly orientated at random.[5] Further, it seems unnatural to suppose that at the crystallization or liquidus temperature there should be an abrupt change from a random to an orderly arrangement of the component atoms. The rate of crystallization of some silicates, *e.g.*, $Na_2O\cdot SiO_2$ and $CaO\cdot SiO_2$, is so great that it is impossible to chill the melt rapidly enough to obtain a glass without crystals. We do not suggest that glass, molten or solid, is physically and chemically homogeneous, but that it consists, especially in the molten state, of groups of atoms linked together in the proportions of the silicates characterized by the equilibrium diagram, so much so that the linkage Na_2O–SiO_2 may be broken approximately seven times as easily as the linkage Na_2O–$2SiO_2$.

Morey argues that

> there is undoubtedly a large amount of combination of these oxides into molecular groupings or compounds, but these groupings are not static but dynamic ..... and such diffuse linkages will give rise to representatives of every possible atomic arrangement and will show a preponderance of those atomic associations which most completely satisfy the potential requirements, but it is doubtful if any more definite picture of compound formation is justifiable.

We would note that it is a dynamic phenomenon which we have investigated and it is our view that the preponderance of these atomic associations which most completely satisfy the potential requirements form the major portion of the diffuse linkages of which Morey speaks. We fail to see why the equilibrium diagram for the Na_2O–SiO_2 system should be regarded on a different basis from other two-component systems, and we interpret the flat liquidus of many of the silicates as meaning, according to Morey, a greater or less degree of dissociation in the liquid state.

In the case of the K_2O–SiO_2 silica glasses,[6] we represented the volatilization-concentration results as Morey has done for the soda-silica glasses, but even there it was undoubted that for glasses in the phase field $K_2O\cdot 4SiO_2$–$K_2O\cdot 2SiO_2$ (accord-

[5] J. T. Randall, The Diffraction of X-Rays and Electrons by Amorphous Solids, Liquids, and Gases. Chap. VI, Part I. Chapman and Hall, 1934.

[6] Eric Preston and W. E. S. Turner, "Study of the Volatilization from Potassium Oxide-Silica Glasses," *Jour. Soc. Glass Tech.*, **17**, 122 (1933).

ing to the equilibrium diagram) the experimental data showed good proportionality between the total loss by volatilization and the excess of K_2O above 28%, that is, the amount of $K_2O \cdot 2SiO_2$ assumed to be present in the liquid state.

It is interesting to observe that in the case of a 17.66% Na_2O–SiO_2 glass, we find a temperature coefficient of volatilization approximately twice as great as that observed in the volatilization of alkali from a 15.94% Na_2O–CaO–SiO_2 glass. Also, that in the case of the Na_2O and Li_2O systems we find no evidence from volatilization data for the existence of compounds $Li_2O \cdot 4SiO_2$ and $Na_2O \cdot 4SiO_2$, while that of $K_2O \cdot 4SiO_2$ does receive indication in accord with the equilibrium diagrams for the three systems.

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VOLATILIZATION AND THE CONSTITUTION OF GLASS

Reply by George W. Morey

Through the courtesy of Eric Preston and W. E. S. Turner, I have been permitted to see the reply[1] to the criticisms of their conclusions in my discussion of "The Constitution of Glass."[2] Under the circumstances I shall restrict myself to discussions of facts cited by me and challenged by them.

Those criticisms were not primarily concerned with the work of Preston and Turner, but were merely incidental to one phase of the discussion in my paper referred to, which explains why their work was not given more extended treatment. The system, Li_2O–SiO_2, had not been published when my discussion was written. The conclusions reached in the paper on the sodium silicate-silica glasses were stated more positively than those in the paper on the potash-silica glasses. The greater number of determinations at 1400°, their greater prominence in the original discussion, and especially the fact that for this temperature alone are sufficient data given to permit recalculation of the original results,[3] explain the choice of this temperature. The criticisms of the results at 1400°, however, are of general application.

I regret the omission of the circles corresponding to glass No. P127 (11.83% Na_2O), which was unintentional and not noticed. I have no objection to the extension of the curves to SiO_2, as suggested. The conclusions I have objected to were those based on Figs. 4 and 7 in the paper of Preston and Turner, reproduced as Figs. 4 and 6 in my discussion, and they both are based on the behavior of the glass, not during the first twenty hours heating alone but throughout the duration of heating. The loss by volatilization of "only 48 milligrams per square centimeter from a total alkali content of approximately 1600 milligrams" is 199 milligrams out of 1574, which changed the gross composition of glass P114 from 48.85% Na_2O at the beginning to 45.57% Na_2O at the end of 20 hours. While the loss is greatest with glass P114, it is significant for all glasses, and my criticism should have been expressed[4]

All of the points for glass P114, as well as for each of the other glasses, are plotted as if the glasses retained their compositions, but in reality they are all of continuously changing composition, and the amount of change is such as to vitiate completely all the conclusions which have been drawn from this figure.

I regret that Preston and Turner feel that I have misrepresented them in my discussion of their Fig. 7 (my Figs. 6 and 7); if I had been writing a criticism of their work I would not have omitted a discussion of the rates of volatilization and the conclusions drawn therefrom. We presumably are agreed that "they fall into two groups because they are calculated on a different basis, but when both are calculated on the same basis (Fig. 7), the weight per cent of Na_2O, a separation into two groups seems no longer to exist"; but we differ in our appraisal of

[1] See preceding paper by Preston and Turner.

[2] George W. Morey, *Jour. Amer. Ceram. Soc.*, **17** [11] 315 (1934).

[3] The original compositions of the glasses are given in Table I, together with losses per unit area at various temperatures; the total losses for the different periods of heating, as well as the weight in grams of Na_2O originally present at 1400°, are given in Table IX; and the final composition of the glasses, together with the total loss of Na_2O for the entire heating at 1400° only are given in Table IV of their paper, *Jour. Soc. Glass Tech.*, **16**, 331 (1932).

[4] G. W. Morey, *Jour. Amer. Ceram. Soc.*, **17** [11] 320, col. 2, line 17 from bottom, *et seq.*

the argument[5] of p. 349 and the legitimacy of the conclusions drawn from the grouping of the curves.

For "a change over from liquid A plus liquid B to liquid B plus liquid C" to have any meaning, the several liquids must be immiscible; otherwise they are not separate liquids, but one liquid of continuously changing composition, and discontinuity in vapor pressure is not possible. The statement that liquids from near sodium metasilicate to beyond sodium disilicate, indeed, throughout the system, form a continuous series of liquids is not begging the question but is a fact of observation. That such is the case was shown by Preston and Turner in their discussion of the constitution of glass.[6] The variations in composition are continuous throughout the system without formation of separate layers or discontinuity in physical properties, and that is all that is necessary. If the composition of the liquid phase can be expressed in terms of Na_2O and SiO_2, without discontinuity, then the chemical potential, μ, of any component must be a continuous function of the amount of that component[7]; and, by virtue of Gibbs' equation 97,

$$[-vdp + \eta\, dt + m_1 d\,\mu_1 + m_2 d\mu_2 \ldots + m_n d\mu_n]$$

the same must be true of the pressure. The value of $\frac{\delta \mu_n}{\delta m_n}$ can only have the value zero at the limit of stability (Gibbs, p. 114). These conclusions are based on the two laws of thermodynamics alone and are independent of any assumptions as to the molecular constitution of the liquid. The case is completely analogous to the change in water content in the system H_2O–$CaCl_2$ from compositions richer in H_2O than $CaCl_2 \cdot 6H_2O$ to poorer in water than $CaCl_2 \cdot 4H_2O$, the liquid being at a temperature higher than the solubility or liquidus curve. As the H_2O content passes over the composition of compounds which would separate at lower temperatures, there is no possibility of a discontinuity of vapor pressure, nor is there any such possibility in the system Na_2O–SiO_2.

The differences in our interpretation of the experimental results are evidently deep-seated and go back to the philosophical question of the evidence necessary to establish the existence of a compound. I believe we are in accord in our rejection of the experimental evidence brought forward by other workers to show the existence of compounds in homogeneous glasses, but not in our appraisal of their own results. I can but join with Preston and Turner in urging those who wish to form a competent opinion on this important subject to have the patience to examine their data, not only for the soda system, but for the potash system as well, to plot it out, and calculate it for themselves. The decision must rest upon the considered opinion of the chemical world, and it should be rendered only after full consideration of the experimental facts.

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[5] E. Preston and W. E. S. Turner, *Jour. Soc. Glass Tech. (Trans.)* **16**, 331 (1932) (p. 349).

[6] Eric Preston and W. E. S. Turner, "Methods of Determining the Constitution of Glass," *Jour. Amer. Ceram. Soc.*, **17** [2] 26 (1934).

[7] The Scientific Papers of J. Willard Gibbs, Vol. 1, p. 110, Longmans, Green & Co., 1906.

THE ANGLE OF FORKING OF GLASS CRACKS AS AN INDICATOR OF THE STRESS SYSTEM*

By F. W. Preston

The tendency of glass cracks to fork, thereby producing dagger-shaped fragments, is one of the things that makes glass dangerous. Glass is almost alone in its ability to form well-developed forking cracks or "radiants." The tendency to fork increases with increasing strength of glass, and the multiplicity of the fissures within the radiant depends on the strength of the glass; but the angle contained within the outermost fissures of a radiant depends primarily on the stress system and not on the numerical value of the greatest stress alone.

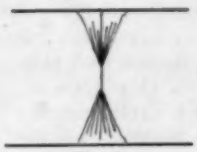

Fig. 1

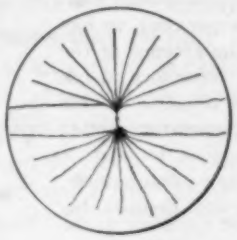

Fig. 2

Fig. 3

Any stress system may be defined by means of three principal stresses, mutually at right angles. We shall consider only two-dimensional cases, the third stress being assumed zero. This means, in effect, that we are dealing with thin or fairly thin sheets of glass, like sheets of window or plate glass, walls of lamp bulbs, or even bottles. Our stress system can then be defined in terms of two principal stresses: in the plane of the sheet and at right angles to each other.

For the purpose of causing a fracture, one of these stresses must be a tension. The other may be a tension or compression. We shall call the greater tension the first stress and denote it by f_x. This is the tension we expect to cause the fracture. The less tension, or compression, is the second stress, denoted by f_y. In many cases f_y is zero, as in testing rods of glass in "simple" tension or in the cross-bending tests of laths.

The stresses are to be measured at or near the point of origin of the fracture. This may be done by photoelastic methods, but the best way for our purpose is to use examples where the stresses can be calculated from theoretical considerations.

The measurement of the angle of forking usually presents no particular difficulty. It should be measured near the initiation of the fork. Individual specimens will vary by a few degrees, but this is probably due more to variations in the experimental set-up than in any tendency of the glass itself to vary much in the angle of forking.

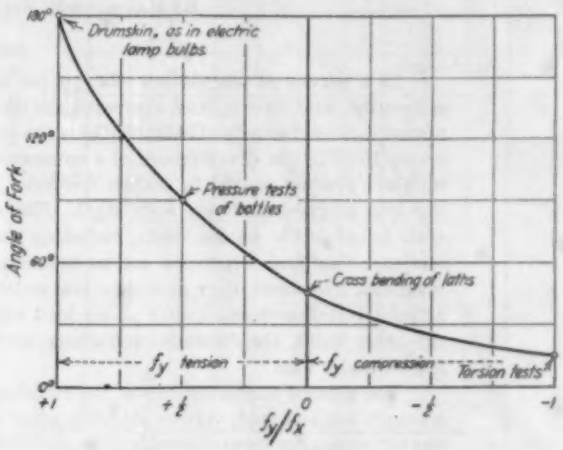

Fig. 4.

In the cross-bending of a lath, for instance, the fork takes the form of Fig. 1. The included angle is θ and by measurement θ is close to 45°, while $f_y = 0$. In the case of a drumskin tension or isotropic tension ($f_y = f_x$); the angle θ is 180°.

In hydraulic tests of cylindrical ware such as bottles, the angle θ is apparently close to 90°. In this case f_y is half f_x.

If a rod or tube of glass be twisted in pure torsion, the greatest tension, f_x, is developed at the surface in a direction at 45° to the axis of the rod, and is accompanied by an equal compression at right angles to the tension (Fig. 3). This amount of compression is not sufficient to suppress forking entirely, and forks of about 15° angle are found. In the case of twisted glass laths, the angle is

* Received March 27, 1935.

usually about 15° for forks occurring in the neighborhood of the origin of the fracture, and 20° or 25° (and even 30° occasionally) in the secondary cracks. These latter figures probably arise from a combination of torsion and bending, and the lower value of 15° or so is more probably the correct one.

With the foregoing data, we may construct a graph as in Fig. 4. Then, if the data are sufficiently accurate, and the belief is warranted that similar stress-systems produce similar fractures, we may measure the forking of any actual fracture and deduce the stress system that produced it.

One caveat must be entered. Glass that has been greatly weakened may not fork at all. The absence of a fork does not imply an infinite or even very high compression for the second stress. As a rule it merely means weak glass.

BUTLER, PA.

FORSTERITE AND OTHER MAGNESIUM SILICATES AS REFRACTORIES*

BY RAYMOND E. BIRCH AND FRED A. HARVEY

ABSTRACT

In a survey of magnesium silicates for use as refractories, experimental studies with talc, serpentine, and olivine, and also with mixtures of these minerals and magnesia (MgO) are reported. Since forsterite ($2MgO \cdot SiO_2$) is the only magnesium silicate which has a stable existence above 1562°C, the development of a commercial magnesium silicate refractory required that the ultimate product should be mainly forsterite. Such a refractory was developed by enriching a low iron magnesian olivine with MgO. The magnesia served to convert certain accessory minerals found in the olivine rocks, including the hydrated minerals (talc and serpentine), to forsterite. Talc and serpentine are so universally present in olivine that, in the absence of the magnesia treatment, they provide a low melting bond which would cause the refractory to fail at relatively low temperatures under load and to exhibit other unsatisfactory properties. On the other hand, the forsterite refractory withstood an exceptionally high temperature before failure under load.

The general characteristics of the refractory are discussed. The data include refractoriness, strength hot and cold, volume stability when reheated, spalling, thermal expansion, chemical behavior, resistance to various slags, thermal conductivity, etc.

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I. Introduction

The end members of the system magnesia–silica ($MgO–SiO_2$) have been of prime importance in the refractories industry for years. In this respect the magnesia–silica system is analogous to the system alumina–silica ($Al_2O_3–SiO_2$). Between alumina and silica there is an essentially continuous series of combinations which constitute the bulk of all manufactured refractories. In the magnesia–silica system, however, the intermediate combinations, the magnesium silicates, have been given little attention until recently. In this country no manufactured magnesium–silicate refractories had been marketed, and in Europe the total production had amounted to only a few hundred tons. The present paper describes the course of a study which culminated in the successful development of a magnesium-silicate refractory of which forsterite, the orthosilicate, is the principal constituent.

The principal mineral forms from which a

magnesium-silicate refractory might be made are the pyroxene mineral, enstatite ($MgO \cdot SiO_2$), the olivine mineral, forsterite ($2MgO \cdot SiO_2$), and the various magnesium hydrosilicates of which serpentine and talc are the commonest members.

II. Survey of Raw Materials[1]

(1) Forsterite

Forsterite has the composition $2MgO \cdot SiO_2$ (57.3% MgO, 42.7% SiO_2). Its density is 3.21 grams per cubic centimeter. In color it may be white, but it is often tinted yellowish, greenish, or gray, probably due to minute amounts of impurities. Its hardness is six to seven.

Forsterite rarely occurs by itself but is common in homogeneous combinations with fayalite ($2FeO \cdot SiO_2$). The mixtures of these two minerals in which forsterite predominates are known as olivine, chrysolite, or peridot. To differentiate from the many varieties of olivine in which magnesia may be only a minor constituent, the word "chrysolite" is preferable to the more generic word "olivine." In the manner of workers at the Geophysical Laboratory who have discussed the "Ca-Fe olivines,"[2] it would also appear proper to use the term "Mg-Fe olivines." The name "dunite" is applied to rock consisting of Mg-Fe olivines alone, or accompanied at most by trivial amounts of accessory minerals.

Mineralogists have determined from chemical analyses and optical data that combinations of forsterite and fayalite exist in nearly all proportions as homogeneous natural mixed crystals. Such a relationship (isomorphism) usually implies that all compositions in the crystal series will possess physical properties which are intermediate and gradational between those of the two end members. Other terms applied to such series, sometimes with a shaded difference in meaning, are "solid solutions" and "mixed crystals."

Since the melting point of fayalite at 1205°C[3] is extremely low as compared with 1910°C[4] for forsterite, it has been supposed that even small percentages of fayalite would seriously lower the refractoriness of olivines of this series. This would be in accordance with the findings of investigations in other isomorphous series; for example, in the feldspar series of which anorthite and albite are the end members,[5] there is considerable liquid developed at temperatures much lower than the melting point of the more refractory member, anorthite, even when only small percentages of albite are present.

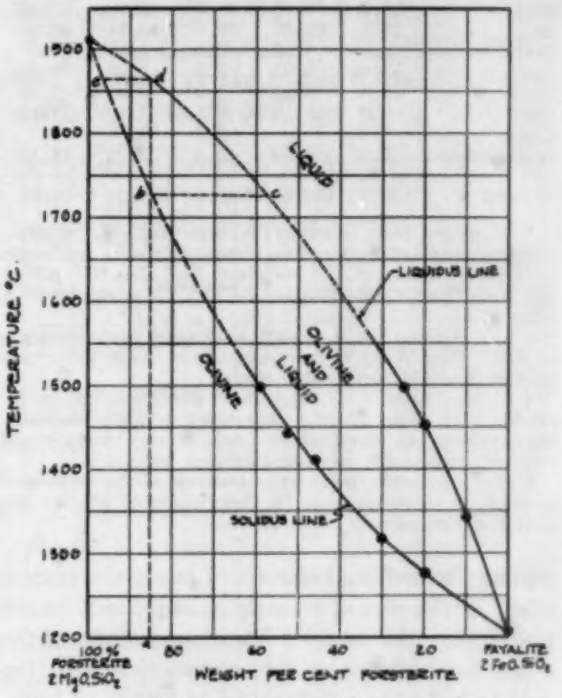

FIG. 1.—Equilibrium diagram of the system forsterite–fayalite ($2MgO \cdot SiO_2$–$2FeO \cdot SiO_2$), after Bowen and Schairer[6] (weight basis).

Within the last few weeks and following the completion of the first draft of this paper, data have been made available by the Geophysical Laboratory, which reveal in their entirety the phase-equilibrium relationships in the Mg-Fe

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[1] Much of the information descriptive of the various magnesian minerals is taken from "Data of Geochemistry" by F. W. Clarke, *U. S. Geol. Surv. Bull.*, No. 770 (1924), and from Dana's Textbook of Geology. Revised by W. E. Ford, 4th ed., 1932. John Wiley & Sons, Inc., N. Y.

[2] N. L. Bowen, J. F. Schairer, and E. Posnjak, "The System Ca_2SiO_4–Fe_2SiO_4 (Calcium Disilicate–Fayalite)," *Amer. Jour. Sci.*, **25** [4] 273–97 (1933).

[3] N. L. Bowen and J. F. Schairer, "The System FeO–SiO_2," *ibid.*, **24** [9] 177–213 (1932).

[4] N. L. Bowen and Olaf Andersen, "The System MgO–SiO_2," *Amer. Jour. Sci.*, **37** [6] 487 (1924). The temperatures taken from this and other papers of the Geophysical Laboratory are revised throughout this paper in accordance with the large-scale "Composition-Temperature Phase Equilibrium Diagrams" recently compiled by Robert B. Sosman and Olaf Andersen, published by the Research Laboratory, U. S. Steel Corp., Kearny, N. J.

[5] N. L. Bowen, "The System Albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$)–Anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$), *Amer. Jour. Sci.*, 4th Ser., **40**, 161–85 (1915).

olivines.[6] These data, shown graphically in Fig. 1, confirm the prevailing impression as to the existence of a complete series of mixed crystals. To illustrate the use of this diagram in determining the melting behavior of any given composition in the series, a single example will be followed. At the base of the diagram, the letter *a* has been placed at the composition 85% forsterite, 15% fayalite; on heating this olivine, the first sign of melting will develop at 1730°C, which is the temperature corresponding to the point *b* at which the vertical line from *a* intercepts the solidus line. The composition of the melt formed at this temperature is found by tracing the vertical from *c* to the base line. As the temperature is increased above 1730°C, the composition of the liquid changes along the liquidus in the direction of *d*. Since the melt in this range is richer in FeO than the original olivine, its separation will serve to impoverish the remaining crystal with respect to FeO and to increase its percentage of MgO; hence while the temperature is rising above 1730°C and the composition of the liquid is changing from *c* to *d*, the remaining crystal changes in composition from *b* to *e*. In the example chosen, the last trace of crystal will disappear and all will be liquid at 1865°C. This temperature is determined by the intersection of the vertical from *a* with the liquidus line. The final liquid will have the same composition as the original olivine (85% forsterite, 15% fayalite) but the last bit of crystal to disappear will have been much richer in MgO, having the composition corresponding to 97% forsterite, 3% fayalite.

In the temperature range from 1730 to 1865°C, the batch will at all times consist of a liquid and a solid phase. At any given temperature within this range, the composition of the liquid and of the remaining crystal may be determined from the intercepts of the horizontal line, representing that temperature, with the solidus and the liquidus lines. Thus *b* and *c*, respectively, represent the solid and the melt in equilibrium at 1730°C; the composition of each may be read from the base line of the diagram (Fig. 1). Similarly *e* and *d* represent the solid and liquid coexisting in equilibrium at 1865°C.

This single example serves to indicate the considerable lowering of refractoriness of Mg-Fe olivine due to replacement of forsterite with fayalite. In the case chosen, it was found that the presence of only 15% of fayalite resulted in liquid formation at 1730°C, which is 180°C lower than the melting point of pure forsterite. Even in the most highly magnesian olivines available

TABLE I

ANALYSES OF MAGNESIAN SILICATE ROCKS

	Soapstone* (%)	Talc** (%)	Serpentine† (%)	Dunite‡ (%)	Serpentine§ (%)
MgO	22.7	30.95	40.3	48.58	37.38
SiO_2	39.1	62.27	36.6	40.11	40.25
FeO		0.85	0.4	6.27	
Fe_2O_3	12.9	0.95	7.3	1.20	6.44
Al_2O_3	12.8	0.15	1.0	0.88	1.38
CaO	6.0		0.1		Trace
Cr_2O_3			0.3	0.56	
Ignition loss	6.6	4.84	13.4	2.74	14.19
Total	100.1	100.01	99.4	100.34	99.64

* Soapstone from Schuyler, Nelson Co., Va.; separate determinations of ferrous-iron compounds were not made.

** F. W. Clarke, *U. S. Geol. Surv. Bull.*, No. 591, p. 339; talc from Huntersville, Fairfax Co., Va.; analysis by E. A. Schneider.

† L. V. Pirsson and A. Knopf, Rocks and Rock Minerals, p. 406. John Wiley & Sons Co., New York, 1926; serpentine from Mount Diablo, Calif.

‡ F. W. Clarke, *U. S. Geol. Surv. Bull.*, No. 591, p. 52; olivine rock from N. C., containing a little chromite; the analysis as given above incorporates some minor recalculations made for simplification purposes.

§ This represents an average analysis of the serpentine used in the investigations, the description of which forms a part of this paper.

TABLE II

DATA ON PURE COMPOUNDS

		Percentage composition before heating				Percentage composition when dehydrated					
Compound	Formula	MgO	SiO_2	FeO	H_2O	MgO	SiO_2	FeO	Density	Mol. wt.	Mol. vol.
Forsterite	$2MgO \cdot SiO_2$	57.3	42.7			57.3	42.7		3.21	140.7	44.0
Fayalite	$2FeO \cdot SiO_2$		29.5	70.5			29.5	70.5	4.0–4.14	203.7	50.0
Enstatite	$MgO \cdot SiO_2$	40.2	59.8			40.2	59.8		3.18	100.38	32.4
Clinoenstatite	$MgO \cdot SiO_2$	40.2	59.8			40.2	59.8		3.28	100.38	30.6
Serpentine	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	43.7	43.3		13.0	50.2	49.8		2.5–2.6	277.1	108.7
Magnesia	MgO	100.0				100			3.6	40.32	11.2
Talc	$3MgO \cdot 4SiO_2 \cdot H_2O$	31.9	63.4		4.7	33.5	66.5		2.7–2.8	379.2	137.9

[6] N. L. Bowen and J. F. Schairer, "The System MgO–FeO–SiO_2," *Amer. Jour. Sci.*, 29 [2] 151–217 (1935).

in commercial quantities, the amount of fayalite seldom is less than 10%. An example of a rock bearing olivine of about this purity is the dunite whose analysis is shown in Table I. Table II may be referred to at this point for a comparison of the analysis of this dunite with that of the individual minerals of which it is constituted.

Apparently forsterite undergoes no inversion from room temperature to its melting point of 1910°C. In a refractory, this property is of much value since some crystal inversions are accompanied by abnormal volume change and since inversions result in adjustments which are not conducive to the stability of the refractory at the inversion temperature.

Referring again to the analogy with the system Al_2O_3–SiO_2, the melting point of forsterite is only 80°C higher than that of mullite, the only compound of alumina and silica stable at high temperatures. A further analogy between mullite and forsterite lies in their very substantial fields of primary crystallization, not only in the binary systems with silica, but also in various ternary systems.[7]

(2) Enstatite and Clinoenstatite

Enstatite, a pyroxene mineral, is a magnesium metasilicate; its composition is $MgO{\cdot}SiO_2$ (40.2% MgO, 59.8% SiO_2). It occurs generally in isomorphous mixtures with the metasilicate of iron ($FeO{\cdot}SiO_2$). The density of enstatite is 3.18 grams per cubic centimeter.

Enstatite is not stable above 1140°C. At that temperature it inverts to clinoenstatite, a compound whose formula is also $MgO{\cdot}SiO_2$ but which possesses different optical properties. (Enstatite is orthorhombic, whereas clinoenstatite crystallizes in the monoclinic system.) The temperature of inversion to the high temperature form, clinoenstatite, is lowered by the presence of $FeO{\cdot}SiO_2$ in solid solution. The minimum inversion temperature occurs at 955°C, and with a composition of 13% $MgO{\cdot}SiO_2$ and 87% $FeO{\cdot}SiO_2$.

Figure 2 shows the phase-equilibrium relationships of the compositions of MgO and SiO_2 of greatest interest. Forsterite and clinoenstatite are the only magnesium silicates having a range of stability at high temperatures.

Clinoenstatite melts incongruently at 1562°C to form 94.5% of liquid and 5.5% of forsterite. In refractoriness, even the pure material is therefore much inferior to forsterite. Although enstatite is a common rock-forming mineral, very pure enstatite rocks are not known in large amounts and probably never will become available for industrial purposes.

(3) Serpentine

Serpentine has the composition $3MgO{\cdot}2SiO_2{\cdot}2H_2O$, the ratio of MgO to SiO_2 being 50.2:49.8, (43.7% MgO, 43.3% SiO_2, and 13.0% H_2O). Its

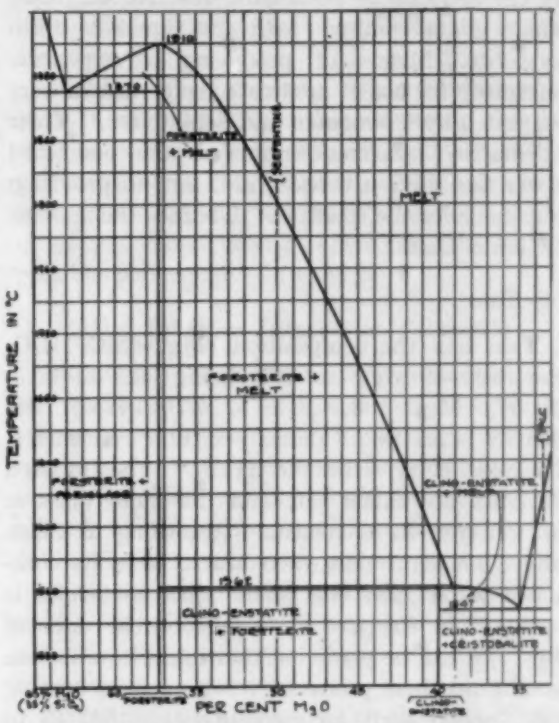

FIG. 2.—The field of the magnesium silicates in the system MgO–SiO_2 after Bowen and Andersen[4] (weight basis).

density is 2.5 to 2.6 grams per cubic centimeter, and its color is commonly green but often yellowish. It occurs in nature only as a secondary product derived from olivine and other magnesian minerals by hydrous alteration.

When heated, serpentine dissociates at 650°C losing its combined water and breaking up into forsterite and free silica, the latter reacting at higher temperatures with a portion of the forsterite to form clinoenstatite. When this reaction is completed, the resultant product from pure serpentine would consist of 58% forsterite and 42% clinoenstatite.

[7] For example, see the phase-rule diagrams collected by F. P. Hall and H. Insley, *Jour. Amer. Ceram. Soc.*, 16 [10] 520, 526, 528, etc. (1933).

At 1562°C all of the clinoenstatite would melt on protracted heating, and the resulting mixture (see Fig. 2) would consist of 60.5% forsterite and 39.5% of a liquid analyzing 39% MgO and 61% SiO_2.

Impure serpentine would be expected to yield more liquid than this and to undergo liquid development at a lower temperature.

From these facts, it becomes evident that to make a high-temperature refractory from serpentine it would be necessary to reduce the amount of liquid phase developed; for example, by the addition of potentially reactive magnesia which could combine with the liquid to form forsterite. Means of producing a serpentine refractory for use at moderate temperatures were suggested by Youngman and Schlotterer.[8] Their calcination treatment removed the combined water and gave a dense grain, but no provision was made for the treatment to reduce the amount of liquid phase.

(4) Talc

Talc has the composition $3MgO{\cdot}4SiO_2{\cdot}2H_2O$, the ratio of MgO to SiO_2 being 33.5 to 66.5, (31.9% MgO, 63.4% SiO_2, 4.7% H_2O). Its density is 2.7 to 2.8 grams per cubic centimeter. In color it is white to green. The foliated varieties are called talc and the more massive are referred to as steatite. According to Clark and Schneider,[9] talc when heated loses its combined water, and one of the silica molecules is split off in the free state. From the data of Fig. 2, it can be predicted that under equilibrium conditions these products, resulting from heating talc, would melt incongruently at 1547°C to produce 95.6% of liquid and 4.4% of cristobalite. In the presence of the natural impurities which occur in talcs, it is probable that the percentage of melted material would be greater than this and that some melting would occur substantially below 1547°C. It is therefore evident that natural talc is not suitable for use as a refractory, except possibly at moderately low temperatures. A rock of which talc is the chief constituent (soapstone), sold in the form of quarried blocks, is used in paper manufacture for lining sulfate smelters in the south and in the northwest. Each of these areas provides natural blocks for this purpose, but the soapstone mined in Virginia[10] is shipped into both districts. An analysis said to be typical of the Virginia material is given in Table I. Its P.C.E. has been found to be cone 16 (which cone Fairchild and Peters found would go down at 1465°C when the heating rate was 150°C per hour). It is probable that temperatures in the sulfate smelters do not exceed 1425°C. Another characteristic, probably of more importance than fusion in terminating the life of soapstone in this service, is its tendency to expand or exfoliate in accordion-like manner when heated. This phenomenon is quite marked in some samples at 1300°C.

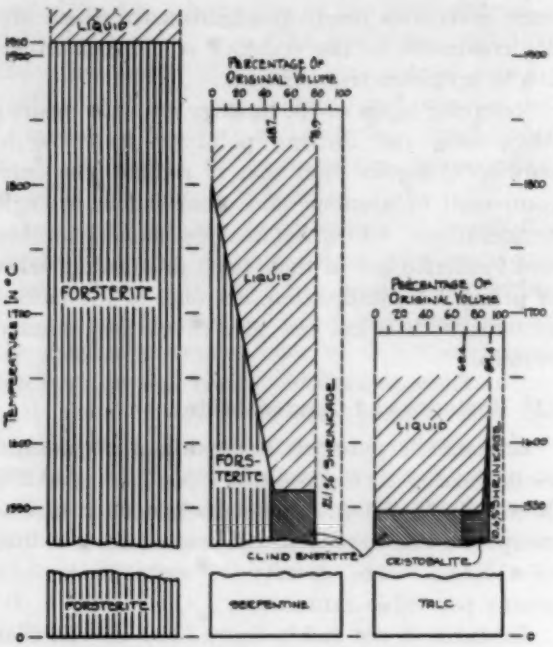

FIG. 3.—Modified equilibrium diagrams showing the behavior of forsterite, serpentine, and talc when heated (volumetric basis).

[8] R. H. Youngman and G. K. Schlotterer, Brit. patent 24,425 (1929).

[9] F. W. Clarke and E. A. Schneider, *U. S. Geol. Surv. Bull.*, No. 78, p. 13 (1891).

[10] For discussions of the origin of the most important Virginia deposit (near Schuyler) and its alteration, see the two following articles by H. H. Hess, (*a*) "The Problem of Serpentinization and Origin of Certain Chrysotile Asbestos Talc and Soapstone Deposits," *Econ. Geol.*, **28** [7] 634 (1933); (*b*) "Hydrothermal Metamorphism of an Ultrabasic Intrusive at Schuyler, Va.," *Amer. Jour. Sci.*, **26** [10] 377 (1933). The first of these two articles has since been commented on by George W. Bain under the subject, "Serpentinization: Origin of Certain Asbestos, Talc, and Soapstone Deposits," *Econ. Geol.*, **29** [4] 397 (1934).

The 1932–33 Minerals Yearbook of the U. S. Dept. of Commerce states that most of the soapstone now marketed is produced in Nelson Co., Va. (in which Schuyler is located).

The course followed in reaching a decision as to the natural magnesium silicates most suitable for commercial use as refractories offers another example of the utility of the phase-rule data worked out by the Geophysical Laboratory. From Bowen and Andersen's study of the system $MgO–SiO_2$,[11] it is at once evident that only two magnesium silicates exist at high temperatures. These are forsterite and the metasilicate known as clinoenstatite. The latter crystal is almost entirely melted at 1562°C, and above this temperature forsterite is the only magnesium silicate which can exist after equilibrium is established.

A summary of the behavior of talc, serpentine, and forsterite can best be made by referring to Fig. 3, which deals with equilibrium relationships reported on the volume basis. By projection from the scales at the top of each column, it is possible to show the condition of each of these natural silicates when heated to various temperatures. Talc dehydrates and forms cristobalite and clinoenstatite, with the latter predominating as shown. Specific volume data indicate that this change should be accompanied by a 10.6% volume shrinkage in the crystal. At 1547°C all of the clinoenstatite melts, and the mass then consists almost entirely of melt with a trace of cristobalite, which goes into solution slowly until it entirely disappears at 1620°C.

Similarly Fig. 3 shows that the dehydration of serpentine is followed by the formation of forsterite and clinoenstatite, with a volume shrinkage of 21.1%. At 1562°C the clinoenstatite melts incongruently to form much liquid and to add a small amount of forsterite to that already present. The remaining solid (48.7% of the initial volume) is now entirely forsterite, which begins to dissolve in the melt at 1562°C; it continues to dissolve with increasing temperature until the last trace disappears at about 1800°C.

Whereas talc and serpentine shrink considerably as a result of the modifications which accompany their dehydration, there is no change of this kind in forsterite. It contains no volatile ingredients and undergoes no inversions. It melts at 1910°C, whereas talc is almost completely melted at 1547°C and serpentine shows only forsterite as a remainder above 1562°C. The study of these relationships made it clear that the problem would be easier to solve by choosing raw materials which would yield a high percentage of forsterite. Talc did not appear to be very promising, since it forms no forsterite upon heating.[12] On the other hand, olivine might represent a percentage of forsterite ranging up to a theoretical 100%, while serpentine of the theoretical composition would yield 53% of forsterite, on the basis of its original weight, and it could be hoped that even more might be developed by suitable enrichment with magnesia, as suggested by Goldschmidt and Knudsen.[12a]

At this point a clear-cut problem was presented, since it was readily seen that no matter whether the raw material chosen was olivine or serpentine, the stability of the refractory at high temperatures would depend very largely upon the degree of success experienced in developing the highest possible percentage of forsterite.

III. Previous Interest in Forsterite

Although to ordinary intents forsterite may be considered to be a new refractory material, rather thorough pioneering has been accomplished by the geologists to the extent that much information is available which should be directly applicable to the development of a refractory in this field. Furthermore, it is not altogether a new trail to the refractories technologist, since forsterite has often crossed his path as a minor constituent in commercial chromite and magnesia refractories.

According to Clarke,[13] the first intentional synthesis of olivine was accomplished by Berthier[14] who reported his findings in 1823.

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[11] N. L. Bowen and Olaf Andersen, "The System MgO–SiO_2," *Amer. Jour. Sci.*, **37** [6] 487 (1924). The many statements made throughout this paper concerning the pyrochemical and melting behavior of mixtures of magnesia and silica are based on the data worked out by Bowen and Andersen.

[12] (*a*) Obviously, however, the plan suggested by V. M. Goldschmidt and R. Knudsen, Brit. patent 260,298, Dec. 3, 1928 (filed Oct. 20, 1926), of heat-treating mixtures of talc and magnesia should be productive of forsterite. This patent is of historical interest since it represents the first demonstration that forsterite could be produced commercially without a melting of the components.

(*b*) W. H. Tyler and W. J. Rees in "An Investigation into the Commercial Utility of a Deposit of Magnesite-Bearing Rocks in the Anglo-Egyptian Sudan," *Trans. Ceram. Soc.* [Eng.], **33** [3] 104–27 (1933), have followed the Goldschmidt-Knudsen plan (see above footnote) of blending magnesia with talc-bearing rock to produce a refractory composed of periclase and forsterite.

[13] F. W. Clarke, *U. S. Geol. Surv. Bull.*, No. 770, p. 393 (1924); Clarke calls it a synthesis of olivine but since Berthier used the constituent oxides it is assumed that not much iron oxide was present.

[14] Berthier, *Ann. Chim. Phys.*, **24** [2] 396 (1823).

Many others succeeded later. Interesting from the point of view of method used are the syntheses of Ebelmen,[15] who crystallized forsterite crystals from boric oxide melts; Daubree,[16] who formed crystals by heating serpentine; and P. Hautefeuille,[17] who fused together the oxides of magnesium and silicon in the presence of magnesium chloride. In Ebelmen's experiments, the boric oxide merely served as a solvent of relatively low melting point from which crystallization could proceed and which was later evaporated by protracted heating.

IV. Development of a Forsterite Refractory

In the initial phase of the investigation of means for producing a forsterite refractory, olivine appeared most promising due to the factors bearing on its stability, which have been discussed. The greater availability of serpentine, however, made it imperative that this mineral should also be considered.

(1) Study of Serpentine

That the theoretical considerations as to liquid formation in serpentine are actually encountered in practice, is shown by Fig. 4. A test piece composed of 100% serpentine, shown on the right, had slumped badly. Its edges were fused and rounded after heating to only 1500°C, whereas a test piece composed of 75% serpentine and 25% of a pure dead-burned magnesia was so stable that it was apparently unaffected at this temperature. (As a matter of fact, it retained its sharp edges upon being heated to 1700°C.) That the serpentine should show such extreme softening at 1500°C, whereas the eutectic in the system MgO–SiO_2 occurs at 1547°C, is attributed to the lowering of the liquidus temperature due to impurities. An analysis typical of the serpentine used is given in Table I.

A further effect of the addition of magnesia to serpentine is shown in shrinkage figures; a test specimen pressed from serpentine alone showed 34% volume shrinkage on heating to 1400°C, whereas a specimen made of 75% serpentine plus 25% magnesia shrank only 4% at this temperature.

Notwithstanding this very great improvement obtained by treating serpentine with magnesia, the process of manufacturing a brick from such mixtures possesses disadvantages not found in using pure olivines.

(2) Study of Olivine

Although olivine is a common constituent of basic pyrogenic rocks, it is one which undergoes alteration with extreme facility and for this reason is seldom free of alteration minerals. As a matter of fact, the work of Bowen and Andersen has shown that before the last trace of melt has disappeared in the solidification of the magma, certain conditions may cause resorption of the forsterite crystals into the melt and the crystallization of clinoenstatite.[18] It is therefore not surprising that even the purer olivine rocks, such as the dunites of North Carolina, may contain the pyroxene minerals (*e.g.*, enstatite and diopside) as important impurities. Even more interest attaches to the subsequent weathering processes which produce talc and serpentine and frequently result in the separation of magnetite or hematite.[19]

FIG. 4.—These cylindrical specimens, initially of the same size, were fired to 1500°C (2732°F) where they were held for five hours. The one on the right was composed 100% of serpentine similar in analysis to the sample shown in Table I, (§). The other cylinder contained 25% MgO added to serpentine of the same selection.

As pointed out previously, the refractoriness of enstatite and each of the principal alteration minerals (serpentine and talc or steatite) suffers in comparison with forsterite, since they melt wholly or in part at relatively low temperatures. The development of a considerable percentage of liquid in a refractory body at furnace operating temperatures need not be viewed with apprehension when the composition is an aluminum silicate; in the system Al_2O_3–SiO_2 the eutectic (between

[15] J. J. Ebelmen, *Ann. Chim. Phys.*, **33** [3] 56 (1851).
[16] A. Daubree, *Compt. rend.*, **62**, 200, 369, 660 (1866).
[17] P. Hautefeuille, *Ann. Chim. Phys.*, 4th Ser., **4**, 129 (1865).
[18] N. L. Bowen and Olaf Andersen, "The System MgO–SiO_2," *Amer. Jour. Sci.*, **37** [6] 499 (1924).
[19] A. N. Winchell, Elements of Optical Mineralogy, Part II, p. 27. John Wiley & Sons, Inc.

mullite and cristobalite) at about 95% SiO_2, 5% Al_2O_3[20] is exceedingly viscous, as are other melts in that system; hence, the refractory continues to exhibit much resistance to deformation in the presence of a certain percentage of the liquid phase. When working in the system MgO–SiO_2, a different set of conditions is faced, since the lowest melting compositions are far less siliceous and apparently very fluid.

As to the apparent high fluidity of magnesium-silicate glasses, the evidence shown throughout this report appears convincing, but it is nevertheless indirect since the glasses were not isolated for study. From equally indirect evidence Tyler and Rees[12b] have reached the contrary conclusion, equally convincing to them, that the melts pro-

FIG. 5.—This nine-inch straight, composed 100% of an olivine rich in hydrated minerals, was set on a magnesite brick and fired to 1450°C. At this temperature an exceedingly fluid melt has drained from the brick.

duced in forsterite refractories made from magnesia and talc are extremely viscous. By far the bulk of the geologic evidence points to the greater fluidity of "basic" melts as compared with alumino-silicates.[21] In view of such evidence, one may wonder with good reason whether Tyler and Rees were not confusing the *quantity* of the melt with its viscosity. A refractory containing a small amount of a very fluid melt might behave similarly to one which contained a larger amount of a more viscous melt.

In observing the behavior, when heated, of lumps of impure Mg-Fe olivine, it was found that a considerable amount of molten material had flowed out of the sample to the furnace hearth. A most interesting example of this phenomenon is shown by the brick in Fig. 5; the brick was composed 100% of an Mg-Fe olivine rock relatively rich in alteration minerals. Firing to 1450°C (cone 18 was down) was sufficient to cause a liquid to sweat out through the pores. This happened in a most interesting manner; upon coming from the kiln, the brick (which was set on edge) looked quite normal at the top face, but drops of glass were showing at the surface of the brick about one-half inch lower down; further down the face of the brick, where it is presumed the pores were more nearly saturated with the melt, the individual drops had combined to form streams of glass which entirely covered the lower portion of the brick and extended to the furnace hearth. Since this firing was only to 1450°C, a full 100° below the eutectic in the system MgO–SiO_2, it is obvious that components other than MgO and SiO_2 entered into the composition of the slag. To find a silicate melt that will drain freely from the pores of a brick is so unusual as to indicate that the melt was very fluid indeed.

The development of molten material at low temperatures in all magnesium silicates other than the orthosilicate, as previously stated, was the reason for confining most of the study to olivine. Since pyroxene as well as serpentine and other hydrous compounds are present (as alteration products) with the olivine, the problem of a liquid phase at low temperatures was not eliminated but merely minimized. Enough liquid was developed from these impurities to impair seriously the load-bearing characteristics of the brick when made from 100% of even the most highly magnesian Mg-Fe olivines.

The problem was solved by combining sufficient magnesia with the olivine to convert all magnesium silicates to the orthosilicate and to allow any magnetite present to be converted to magnesio-ferrite ($MgO{\cdot}Fe_2O_3$). Only by carrying these reactions largely to completion could a sufficiently stable refractory be formed from partially hydrated olivines.

NOTE: This was also recognized by Goldschmidt and Knudsen, whose work was done independently in Norway, chiefly in the laboratory of the Government Raw Material Committee in coöperation with the Norwegian Ministry of Trade and Industry. The work started by Goldschmidt and Knudsen has been continued by Goldschmidt, partly in coöperation with German companies.

[20] N. L. Bowen and J. W. Greig, "The System Al_2O_3–SiO_2," *Jour. Amer. Ceram. Soc.*, 7 [4] 238–54 (1924).

[21] N. L. Bowen, "Viscosity Data for Silicate Melts," *Trans. Amer. Geophys. Union.*, pp. 240–55 (1934).

Following this method of attack (magnesia enrichment), the operating details were solved, and a refractory composition which is essentially a forsterite refractory was developed. Since such a refractory has not previously been described, it is believed it will be of interest to give the principal properties of the commercial product.

V. Properties of the Forsterite Refractory

(1) Composition

The forsterite refractory referred to in subsequent paragraphs is of the analysis given under column *aa* in Table IV. It was made by enriching with magnesia a highly magnesian olivine containing a low percentage of fayalite. The brick were fired in a commercial magnesite brick kiln.

(2) General Characteristics

The forsterite refractory may be considered to be composed of olivine grains bonded by a recrystallized structure of forsterite, produced by the reaction of magnesia with the melted silicates and other products resulting from the heat treatment of the minor amounts of talc and serpentine present in the crude rock; an appreciable percentage of undissolved magnesia is present as periclase.

The brick weigh about 155 pounds per cubic foot and therefore have a bulk specific gravity of 2.50. This is slightly less than most magnesite brick (2.4 to 2.7), considerably less than chromite brick (about 3.0), and much higher than silica and fireclay brick (1.7 and 1.75 to 2.15, respectively).

The range of apparent porosity in the forsterite brick is ordinarily from 24 to 28%.

The density of the material composing an average sample of forsterite brick has been found to be 3.36 grams per cubic centimeter. That this is higher than the 3.216 reported for forsterite[22] is not surprising since the brick contains an appreciable percentage of periclase ($d = 3.6$)[23] and since fayalite present in olivine in solid solution raises its density.[24]

(3) Refractoriness

Forsterite has a melting point of 1910°C. Goldschmidt[25] reports that the American-made forsterite brick under discussion has a fusion temperature between 1850°C and 1900°C.

When tested by the A.S.T.M. method for softening point,[26] some of the mixes studied during the development of the forsterite brick showed a pyrometric cone equivalent of 38. It is believed that subsequent improvements have raised the refractoriness by an appreciable extent, but cone 38 is the highest cone which can be reached with the testing equipment available. This cone was found by Fairchild and Peters[27] to correspond to a temperature of 1835°C when the test cones were heated at a rate of 150°C per hour.

(4) Strength

The cold crushing strength of forsterite brick (about 2000 lb. per sq. in. on end) is comparable to that of silica brick but is somewhat less than that of most magnesite brick. It has, of course, been shown that the very great cold strength of magnesite brick is due to the presence of silicate glasses, whose very presence is also responsible for their weakness when heated.

In strength at high temperatures, forsterite brick are indeed exceptional for basic refractories. With the equipment available, it has seldom been possible to test the brick above 1550°C (2822°F), but even after a 90-minute hold at this temperature under a load of 25 pounds per square inch, forsterite brick show a linear subsidence of less than 2%. The excellence of this behavior is apparent from a comparison with other refractories as given in Table III.

(5) Spalling

Forsterite brick appear to show about the same resistance to thermal shock as the special low iron magnesite brick which have appeared in recent years on the American market. They are, therefore, more resistant to spalling than ordinary magnesite brick and, in general, may be grouped with the very best brick of this class. This conclusion is based largely upon their behavior in panel spalling tests. The test furnace has

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[22] N. L. Bowen and Olaf Andersen, "The System MgO–SiO_2," *Amer. Jour. Sci.*, **37** [6] 498 (1924).

[23] E. S. Larsen, "The Microscopic Determination of the Nonopaque Minerals," *U. S. Geol. Surv. Bull.*, No. 679, p. 177 (1921).

[24] J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. 6, p. 387. Longmans, Green & Co., London, 1925.

[25] V. M. Goldschmidt; personal communication.

[26] Amer. Soc. Test. Mat., "Standards on Refractory Materials," Feb., 1935; Method C24–33, p. 50.

[27] C. C. Fairchild and M. F. Peters, "Characteristics of Pyrometric Cones," *Jour. Amer. Ceram. Soc.*, **9** [11] 701–43 (1926).

been described in this *Journal*,[28] and the method, with a few modifications, corresponds to that recently adopted by the A.S.T.M. as a tentative procedure for resistance to thermal and structural spalling.[29] The brick were laid flat, without mortar, to form a panel seven brick high; the panel was then placed against the open side of a furnace maintained at 1100°C; after 20 minutes of heating the panel was removed and chilled for 20 minutes with an air blast applied evenly over its face; it was then returned to the furnace and the alternate heating and cooling was repeated to a total of ten cycles.

TABLE III

Behavior when tested in A.S.T.M. standard load test furnace with load of 25 lb./sq. in. bearing on end of brick (typical data)

Type of refractory	Temperature of collapse	Linear subsidence after 90 min. at 1350°C (2462°F)	Linear subsidence after 90 min. at 1450°C (2642°F)
Forsterite	Above 1550°C (2822°F)	None	Trace
Silica (lime-bonded)	1630°C (2966°F)	None	Trace
Chromite	1400°C (2552°F)		Collapses
Magnesite brick (2.1% Fe_2O_3)*	1525°C (2777°F)		
Magnesite brick (6.0% Fe_2O_3)	1420°C (2588°F)		Collapses
Super-duty fireclay brick (42% Al_2O_3)		1.5%	5.0%
High heat duty fireclay brick (39% Al_2O_3)		5.0%	10.0%+
Diaspore brick (60% Al_2O_3)		1.0%	5.0%
Diaspore brick (50% Al_2O_3)		1.5%	7.0%

* It is not intended to suggest that the improvement in the low iron magnesite brick is due entirely to the reduction in Fe_2O_3 content; there are reasons for believing that other differences in analysis, as shown by Table IV, are of perhaps greater importance.

In this panel spalling test, the forsterite brick show 0 to 5% loss. Usually the special low iron, low spalling magnesite brick show a loss within this range, while magnesite brick of the more common type will show a loss of about 10 to 20%.

(6) Volume Stability

Forsterite brick show negligible permanent volume change at open-hearth furnace temperatures. When exposed on all sides for five hours to a temperature of 1600°C, the average linear shrinkage of twelve brick was only 0.5%.

(7) Thermal Conductivity

The thermal conductivity of the forsterite brick was found to be much lower than that of magnesite brick and even lower than that of silica brick except at temperatures below 700°C. The temperature coefficient was found to be negative, although the diminution in conductivity with increasing temperature was far less than that of magnesite brick.

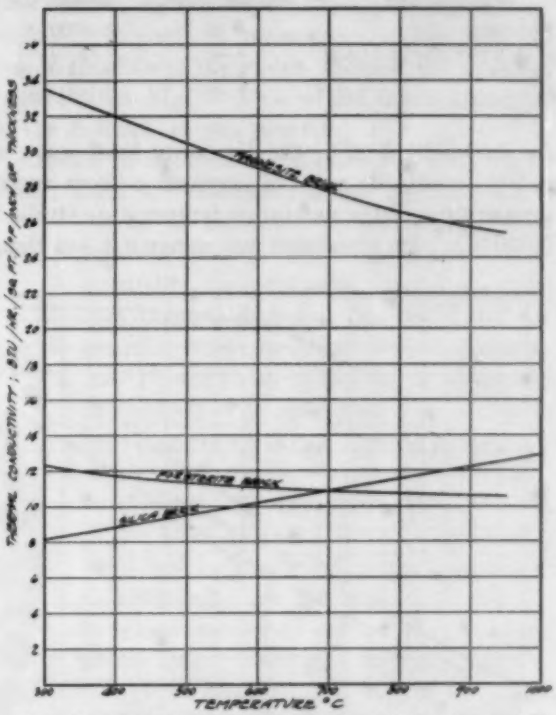

FIG. 6.—The thermal conductivity of the forsterite refractory compared with that of silica and magnesite brick.

The conductivity tests on forsterite brick were run with an apparatus of the type described by Wilkes.[30] The data are given in the table which follows and in Fig. 6.

Average temp. (°C)	Thermal conductivity (B.t.u./hr./sq. ft./°F/in.) Forsterite brick	Magnesite brick*	Silica brick*
250	12.7	34.5	7.8
300	12.3	33.5	8.1
400	11.7	31.9	8.8
500	11.3	30.5	9.5
600	11.0	29.0	10.2
700	10.8	27.7	10.8
800	10.7	26.5	11.5
900	10.6	25.7	12.2
950	10.5	25.3	12.5

* Modern Refractory Practice. Harbison-Walker Refractories Co., 1929.

[28] S. M. Phelps, S. M. Swain, and R. F. Ferguson, "A Service Test for Refractories," *Jour. Amer. Ceram. Soc.*, **14** [5] 389–402 (1931).

[29] Tentative Method C38-34T, A.S.T.M. Standards on Refractory Materials, p. 31, Feb., 1935.

[30] G. B. Wilkes, "Thermal Conductivity of Magnesite Brick," *Jour. Amer. Ceram. Soc.*, **16** [3] 125–30 (1933).

(8) Thermal Expansion

Tests were run to determine the reversible thermal expansion of forsterite brick as compared with other refractories; the results follow.

Type of brick	Total linear thermal expansion (20–1000°C) (%)	Average coefficient of expansion (20–1000°C)
Forsterite	1.05	0.0000107
Magnesite (2.1% Fe_2O_3)	1.29	0.0000132
Chromite	1.06	0.0000108
Silica	1.45	0.0000148

As shown by Fig. 7, the forsterite brick gave a nearly constant rate of expansion from room temperature to the maximum temperature studied (1000°C). Its expansion was somewhat less than

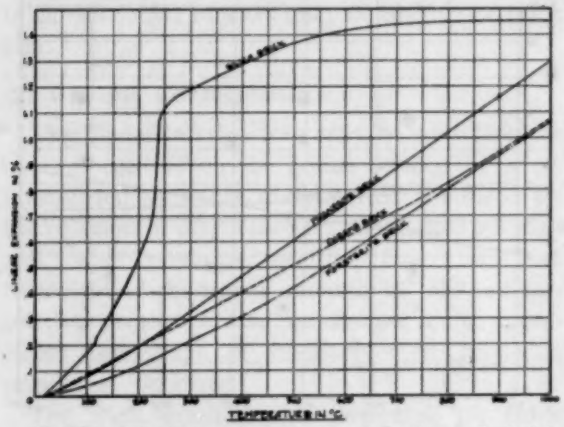

FIG. 7.—The thermal expansion of the forsterite brick compared with that of other refractories.

that of magnesite brick throughout most of this range and likewise perceptibly less than that of the chromite brick.

These data for the thermal expansion of forsterite brick are almost the same as those reported by Heindl and Pendergast[31] for briquets of olivine fired to 1400°C. Their data for the two olivines most similar in analysis to that which was used in the forsterite brick show average coefficients of expansion (20 to 900°C) of 0.0000108 and 0.0000111.

The value of 1.45% total linear expansion to 1000°C given above for silica brick is in close agreement with the best published data. The work of various investigators, however, shows considerable divergence in the reported rate of expansion at individual temperatures, particularly below 600°C. This is explainable by the different percentages of quartz, cristobalite, and tridymite in various samples of brick. Each of these allotropic forms of silica expands at a different rate. The reversible thermal expansion of silica brick as a class should properly be shown as a band diagram so as to indicate that its rate of expansion, especially at low temperatures, may vary widely. The curve for reversible thermal expansion of silica brick given in Fig. 7 is typical of silica refractories with a degree of inversion commonly found.

(9) Hydration and Effect of Acids

Olivine is one of the easily alterable minerals. Autoclave tests show that, like magnesite brick, forsterite brick can be hydrated rather readily by steam. All tests made to date on the forsterite brick indicate that it is affected to about the same extent as magnesite brick. After being treated for one hour in an autoclave with steam at 75 pounds per square inch, both types of brick are easily crumbled.

Mellor[32] reports that olivine is gelatinized by sulfuric acid and that it is quite soluble also in concentrated hydrochloric acid, with the more ferruginous varieties dissolving the faster; silicic acid separates.

(10) Microscopic Studies and Mineralogical Composition

(*a*) *The Crude Rock:* The appearance of a thin section of dunite typical of that used in making forsterite brick is shown in Fig. 8. Many of the fissures between the olivine grains are filled with serpentine; the talc occurs in flakes and in patches of flakes. Nearly all analyses of dunite have shown traces of Cr_2O_3; inspection of thin sections shows occasional chromite grains as a crystalline impurity imbedded in the olivine. The chromite particles are of such a size as to give no indication of having been precipitated from solid solution.

It is not entirely evident in what form the aluminous constituent of dunite (0.8 to 1.2% observed) is present. It may be present as any one of several different minerals.[33]

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[31] R. A. Heindl and W. L. Pendergast, "Olivine as a Refractory," Bur. Stand. R. P. 645; also *Bur. Stand. Jour. Research*, **12**, 215–22 (1934).

[32] See footnote 24, p. 184.

[33] In a personal communication, V. M. Goldschmidt states that "one of the common constituents containing alumina is chlorite, a complex hydrated silicate of magnesia and varying amounts of alumina and iron. The chlorite in most cases is probably an alteration product

Pyroxenes are common constituents of the North Carolina olivine rocks, although none is evident in the thin section of Fig. 8. Goldschmidt reports that there are two types of pyroxenes common in such rocks, enstatite ($MgO \cdot SiO_2$) and a pyroxene of the diopside family. The mineral diopside has the formula $CaO \cdot MgO \cdot 2SiO_2$. This pyroxene contains most of the lime of the olivine rocks.

(*b*) *The Fired Forsterite Brick:* In Fig. 9 are shown two photomicrographs of thin sections of a forsterite brick. The magnification is such as to show prominently not only the olivine but also the unconsumed periclase (MgO). A fine mosaic of secondary forsterite forms the bond between the original forsterite (olivine) grains and the periclase, filling whatever spaces are available.

FIG. 8.—Photomicrograph (70 ×) of dunite thin section. This typical section shows serpentine in many fissures, and a single flake of talc. (Key: *S* = serpentine, *T* = talc, and *O* = olivine.)

The space in the fissures originally filled by serpentine is now filled by forsterite or highly forsteritic olivine apparently of secondary development. As discussed earlier in this paper, serpentine breaks down into products which consist only of forsterite and melt. It is likely that the liquid developed from the serpentine, originally present in these fissures, has drained out to the face of the grains where it has actively engaged the MgO. This would leave forsterite in the fissures, as was observed.

Around the olivine grains (even the larger ones), there are reaction rims of olivine or forsterite of secondary development which indicate that the MgO has reacted so as to modify the surfaces of the grains. The fact that no magnesia is now found in contact with many of these particles may be due to its having been consumed in reaction or in some cases to particles breaking away in the process of making the section.

Although magnesio-ferrite ($MgO \cdot Fe_2O_3$) in the fired forsterite brick is not easily identified by the usual optical methods, Goldschmidt has pointed out that it is easily recognized by its strong ferromagnetism. The raw olivine rock or the green brick do not deflect the magnetic needle. The finished brick, however, shows strong magnetic permeability and deflects a magnetic needle held at a distance of several inches. If magnetite is formed in firing the brick, it too would have contributed to this effect. Although Fig. 9 does not show it clearly, most of the olivine grains in the brick appear as translucent as before heat treatment. This has not invariably been the case; the grains existing in some fired olivine mixtures have been found to show a heavy precipitation of yellowish brown inclusions. This is believed to indicate an oxidation of a certain amount of the iron compounds. This phenomenon has been reported also by Insley.[84]

These petrographic studies of the fired forsterite brick indicate that the treatment with magnesia has succeeded in converting the pyroxene minerals as well as the breakdown-products of the hydrosilicates (talc and serpentine)

from phlogopite, a magnesian mica, which is found in small amounts (mostly one or a few per cent) in many dunite rocks. Another common constituent containing alumina is plagioclase feldspar. Sometimes one also encounters spinel ($MgO \cdot Al_2O_3$) and corundum as primary constituents of olivine rocks. In many cases, alumina is found as a minor constituent of amphibole, which is a rather common primary constituent of olivine rocks, especially amphibole of the anthophyllite-gedrite series, being members of the group of magnesium hydrosilicates. These amphiboles may contain several per cent of alumina. Also some small amounts of alumina may enter into the pyroxenes which occur in the olivine rocks."

[84] Herbert Insley on results reported by Heindl and Pendergast; see footnote 31.

FIG. 9.—Photomicrographs (70 ×) of two thin sections of the forsterite refractory. The darker particles are periclase, the lighter ones are highly forsteritic Mg-Fe olivine and recrystallized forsterite.

into a secondary structure of forsterite which serves to bond the refractory. The product consists of a highly forsteritic Mg-Fe olivine and a minor amount of periclase bonded together with secondary forsterite.

(11) Basicity

It could be expected that forsterite would be less basic than magnesia and less acidic than silica, with the final determination of its reactivity depending upon the nature of the second reacting substance.

A series of tests was run with the dual purpose of determining the basicity of the forsterite refractory and of finding out the limiting temperature to which it could safely be laid up in contact with refractories of other types.[35] Two brick or half-brick, one of forsterite, the other of some differing composition were set face to face, and with one resting on the other, they were heated in an oxidizing atmosphere to various temperatures in a laboratory furnace. The temperatures were 1300, 1400, 1500, 1600, and 1700°C. In the 1700°C test, the maximum temperature was held for a time not exceeding one hour, but in each of the other firings, the temperature was held at the maximum for five hours. In order that the heat treatment would not be cumulative, different samples were used at each temperature. The test was run on forsterite brick paired with brick of the following materials: (*a*) silica, (*b*) low iron magnesite, (*c*) ordinary magnesite, (*d*) high alumina (70% Al_2O_3), (*e*) fire clay, and (*f*) chromite. The chemical analyses of each of these refractories are given in Table IV, where the column headings correspond to the foregoing letters.

The results of these tests follow:

[35] For similar studies on refractories other than forsterite, see R. E. Birch, *Amer. Refrac. Inst. Bull.*, No. 52, Oct., 1934.

Forsterite on	Lowest temperature at which trace of reaction was observed	Lowest temperature at which reaction was observed to be damaging to either brick
Silica	1700°C	1700°C
Low iron magnesite	No reaction	No reaction
Ordinary magnesite	No reaction	No reaction
High alumina	1700°C	1700°C
Fire clay	1500°C	1600°C
Chromite	No reaction	No reaction

TABLE IV

ANALYSES TYPICAL OF THE FORSTERITE BRICK AND OF OTHER COMMERCIAL REFRACTORIES INCLUDED IN THE REACTION STUDIES

Type of refractory	(aa) Forsterite	(a) Silica	(b) Low iron magnesite	(c) Ordinary magnesite	(d) High alumina	(e) First quality fire clay	(f) Chromite
SiO_2	31.7	95.9	2.0	3.5	22.7	52.9	5.0
Al_2O_3 + TiO_2	1.1	1.0	0.7	1.0	74.5	42.7	29.5
FeO	6.4						13.3
Fe_2O_3		1.0	2.1	6.0	1.8	2.3	
CaO	2.8	2.0	1.7	3.7	0.1	0.3	Trace
MgO	57.2	0.1	93.6	85.7	0.3	0.4	17.8
Cr_2O_3	0.1						32.7
Total	99.3	100.0	100.1	99.9	99.4	98.6	98.3

Most surprising of the results of this test is that the forsterite refractory showed no appreciable reaction with magnesite brick and so little reaction with silica brick at the temperatures involved. Figure 10 contrasts the behavior of forsterite and magnesite brick when each was set on a silica brick and heated to 1600°C. The forsterite-silica contact face remained dry with no apparent reaction; in strong contrast, the reaction between magnesite and silica brick was so violent that the chunk of magnesite brick cut a broad channel entirely through the silica brick. It is necessary to avoid the conclusion that forsterite and silica brick can always be safely used in contact with each other. Complicating factors in actual service are the presence of slags, fly-ash, and highly reducing atmospheres. In firing forsterite brick in oil-fired kilns, it has been noted that they sometimes show some reaction with the silica brick upon which they are set at temperatures which do not exceed 1480°C. Furthermore, Bowen and Schairer[36] have found that there can be no true equilibrium (at the temperatures of these reaction tests) between silica and forsterite or highly forsteritic Mg-Fe olivines.

These tests indicate that forsterite is most reactive with fireclay brick of the common refractories, and that the two refractories should not be used in contact with one another at 1500°C or higher.

Full consideration of the data derived from tests and of the behavior of the brick in service indicate that the forsterite product will usually act as a basic or basic-to-neutral refractory.

[36] See footnote 6.

VI. Miscellaneous Notes—Rational Analysis

A method has been derived which permits the estimation of the percentages of the principal minerals present in samples of olivine-bearing rock. This method was of particular usefulness in determining whether sufficient talc and serpentine were present to account for the formation of the low melting liquid which ran out of certain experimental brick.[37] Any such process of calculation is obviously subject to error and many of the errors are made knowingly, but even then the results may be worth the compromise. The errors are naturally minimized when chemical analyses are supplemented by petrographic examination.

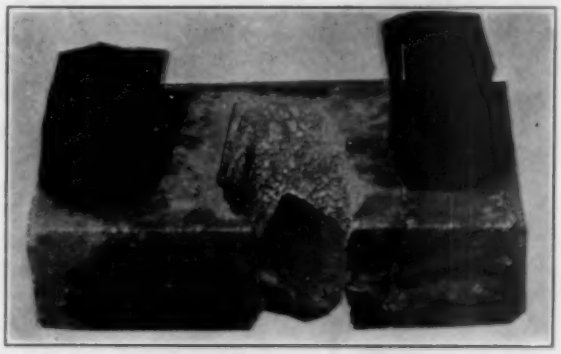

FIG. 10.—This photograph contrasts the appearance of low iron magnesite brick and forsterite brick in contact with silica brick after heating to 1600°C. The quarter-brick of low iron magnesite which formerly rested on the face of the silica brick has cut a swath entirely through the silica brick. The staining of the latter brick due to slag absorption is evident. The samples of forsterite brick on either end show little or no reaction with the silica brick at this temperature.

This method assumes that there is no weathering of the iron compounds. This introduces an error which is not great in the highly magnesian olivine with which we are concerned. The method, however, should not be applied to the highly weathered and highly oxidized rock,

[37] The percentages of fayalite and forsterite in the olivine can be estimated by optical methods; see N. H. Winchell, Elements of Optical Mineralogy, Part II, p. 168. John Wiley & Sons, Inc., 1927.

characterized by reddish brown color and soft pasty consistency. In these, much of the iron may be hematite and limonite, the presence of which introduces too much of a disturbing factor in the allotment of SiO_2 and the ignitable ingredients.

The calculations were carried out in several steps as follows:

(1) Calculate all Cr_2O_3 as chromite, $FeO \cdot Cr_2O_3$.

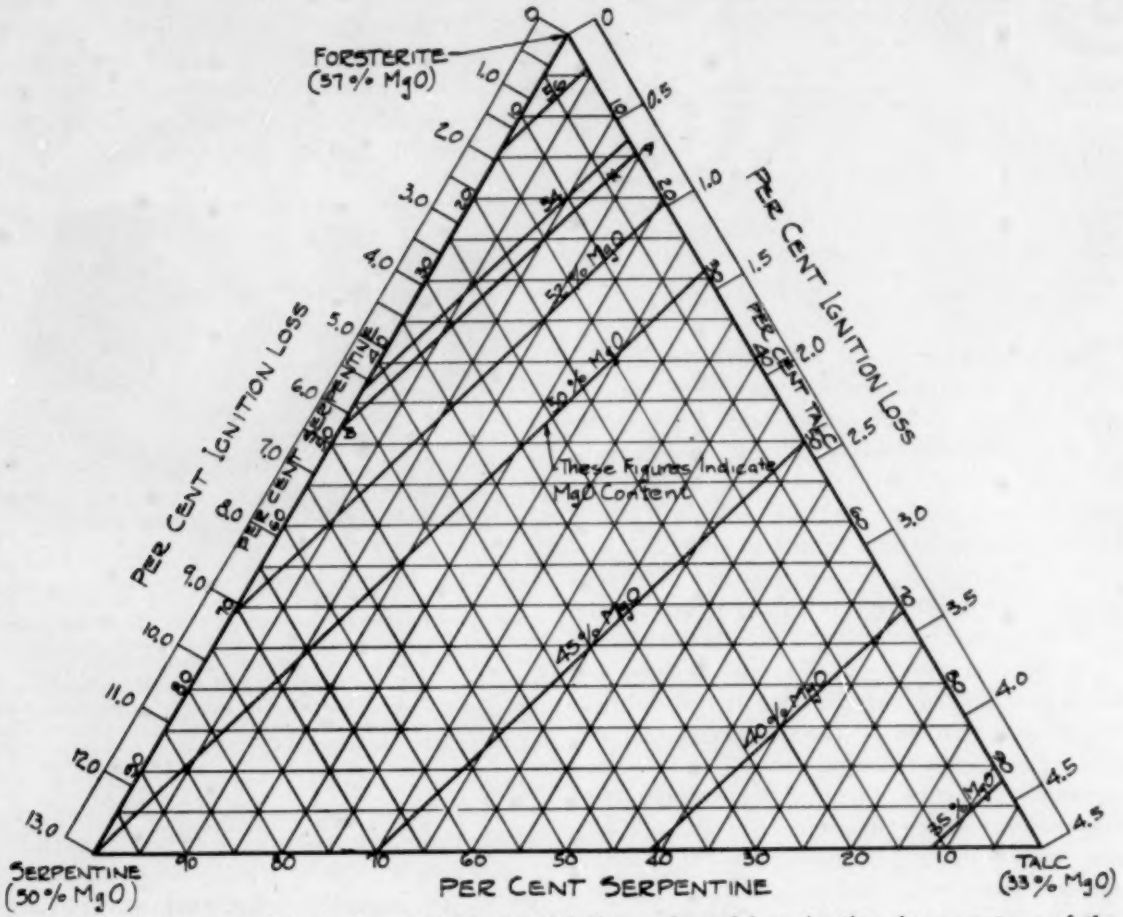

FIG. 11.—In the system of rational analysis, this triaxial diagram is used in estimating the percentages of the various magnesium silicate minerals in samples of olivine rocks.

(2) Calculate all Al_2O_3 as chlorite, assuming its composition to be 30% SiO_2, 20% Al_2O_3, 35% MgO, 15% H_2O.

(3) Calculate all lime as diopside, $CaO \cdot MgO \cdot 2SiO_2$ (actually some of the lime will be present as hedenbergite, $CaO \cdot FeO \cdot 2SiO_2$).

(4) Calculate all remaining FeO as fayalite ($2FeO \cdot SiO_2$).

(5) From the MgO and SiO_2 not accounted for in steps 1, 2, 3, and 4, the ratio of MgO to MgO + SiO_2 is calculated as a percentage. If the ratio approximates 57.3% (the percentage of MgO in forsterite), it may be assumed that the amounts of magnesium silicates, other than forsterite, are trivial and that the percentage of forsterite is equal to the total of the MgO + SiO_2 left over from steps 1, 2, 3, and 4. Three samples representing carloads of dunite (columns *a*, *b*, and *c* in Table V) have shown, at this point in the calculations, MgO : MgO + SiO_2 ratios of 57.0, 56.2, and 56.6%. It is felt that this provides a fairly satisfactory confirmation of the value of the method and that it is as close as one could expect to come with it, particularly since the method neglects the occurrence of enstatite.

(6) If the rock is a true olivine, the percentage of MgO calculated in step 5 should not exceed 57.3% by an amount equalling the error of the

chemical analysis and the calculation method. If it is much less than 57.3% and if step 2 leaves an excess of chemically combined water (ignition loss), it would appear that there had been an alteration of the olivine to form serpentine and talc. The relative percentage of each can be obtained by graphic or mathematical solution.

An example is given of the graphic method as applied to sample *d* (Table V). When step 4 of the rational analysis was reached, the remaining constituents were as follows:

$$\text{MgO} = 43.02\%$$
$$\text{SiO}_2 = 37.22\% \qquad \frac{43.02}{43.02 + 37.22} = 53.6\%$$

Ignition loss (0.58% accounted for in clay) = 0.95 ÷ (43.02 + 37.22 + 0.95) = 1.17%.

First, referring to Fig. 11, the line representing 53.6% of MgO is located. The ignition loss of the two end-points of this line (*A* and *B*) are read from the side-scales as 0.7 for *A* and 6.3 for *B*. The ignition loss of the mixture under discussion is 1.17%, which would indicate that its composition on the line *AB* lies quite close to point *A* whose ignition loss is 0.7%. As a matter of fact, it lies at a point which is 92% of the distance from *B* to *A;* this was determined as follows:

$$\frac{6.30 - 1.17}{6.30 - 0.70} \times 100 = \frac{5.13}{5.6} \times 100 =$$
92% of distance from *B* to *A*

The obviousness of this solution is shown by the following diagram (the "lever reaction"):

B	*X*	*A*
6.3	1.17	0.7
5.13		
5.6		

TABLE V

ANALYSES OF SEVERAL DUNITES

	(*a*) (%)	(*b*) (%)	(*c*) (%)	(*d*) (%)
SiO_2	40.3	40.58	41.10	43.54
Al_2O_3	1.1	1.08	1.16	0.78
FeO	6.4	7.56	5.79	8.94
MnO			0.18	0.25
Cr_2O_3	0.30	0.33	0.16	0.26
CaO	0.2	0.10	0.30	0.67
MgO	49.3	47.56	49.27	44.88
Ignition loss	1.0	1.16	0.50	1.53
Totals	98.6	98.37	98.46	100.85

ESTIMATED MINERALOGIC COMPOSITION*

	(%)	(%)	(%)	(%)
Forsterite	82.8	81.2	83.2	67.0
Fayalite	8.9	10.7	8.2	12.7
Serpentine	Trace	Trace	Trace	3.2
Talc	Trace	Trace	Trace	11.0
Chlorite	5.5	5.4	5.8	3.9
Diopside	0.8	0.4	1.1	2.6
Chromite	0.4	0.5	0.2	0.4
Total	98.4	98.2	98.5	100.8

* Enstatite is present in most dunites but was not determined by the method of rational analysis used.

Knowing that the composition was at a point 92% of the entire distance from *B* to *A*, its location was readily found on Fig. 11 at *X*. This point corresponds to the following composition, forsterite 82.5%, serpentine 4.0%, and talc 13.5%.

Since the magnesium silicates constitute only 81.19% of the entire sample (37.22 + 43.02 MgO + 0.95 H_2O), the following calculations are necessary to establish the percentage of each mineral in the rock:

$$\text{Forsterite} = 0.812 \times 82.5 = 67.0$$
$$\text{Serpentine} = 0.812 \times 4.0 = 3.2$$
$$\text{Talc} = 0.812 \times 13.5 = 11.0$$

Dunite, such as sample *d*, to which the calculations just explained were applied, is inferior to samples *a*, *b*, and *c* of Table V for the manufacture of refractories before being treated with magnesia. A brick made of such a dunite deformed even in firing to cone 18. It is theorized that the melt developing from the talc and serpentine carried the aluminous impurities as well as some magnetite and limonite ($Fe_2O_3 \cdot nH_2O$) into solution so as to produce an extremely fluid liquid.

VII. Summary

In a survey of magnesium silicates for use as refractories, experimental studies with talc, serpentine, and olivine, and also with mixtures of these minerals and magnesia (MgO) are reported. Since forsterite ($2MgO \cdot SiO_2$) is the only magnesium silicate which has a stable existence above 1562°C, the development of a commercial magnesium silicate refractory required that the ultimate product should be mainly forsterite. Such a refractory was developed by enriching a low iron Mg-Fe olivine with MgO. The magnesia served to convert the hydrated minerals found in the olivine (talc and serpentine) to forsterite and had a similar effect on the enstatite

also present as an accessory mineral. Talc and serpentine are so universally present in olivine that, in the absence of the magnesia treatment, they provide a low melting bond which would cause the refractory to fail at relatively low temperatures under load and to exhibit other unsatisfactory properties. On the other hand, the forsterite refractory showed only slight subsidence after 90 minutes at 1550°C under a load of 25 pounds per square inch. One of the unanticipated properties of the forsterite refractory is its low thermal conductivity.

In view of their incompleteness at the present time, service data have been excluded from the scope of the present paper, which has therefore been confined to the development and properties of a forsterite refractory. Service tests are being conducted, and it is hoped that a report can be made on them at a later date.

Acknowledgments

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The authors appreciate the assistance of C. R. Fettke, who made petrographic examinations of raw materials and brick, and acknowledge their indebtedness to V. M. Goldschmidt, whose kindly criticism of the manuscript resulted in important revisions of the paper. His comments appear at several places through the manuscript, particularly in the section on Mineralogical Composition.

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CERAMIC ABSTRACTS[1]

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Abrasives

Hardness tests for grinding disks. O. and W. *Schleif. & Poliermittel-Ind.*, Nos. 23–24, p. 197 (1934); abstracted in *Tonind.-Ztg.*, **59** [14] 185 (1935).—A machine (Ger. Pat. 593,089) tests the hardness of grinding disks by direct mechanical strain on the grinder using rotating testing instruments. The grinding disk is started turning concentrically and the testing body is pressed with a definite constant pressure against the disk. It rolls without wearing the grinding disk. The penetration of the body into the disk, which corresponds to the efficiency of the disk, is read from a meter. M.V.C.

PATENTS

Abradant sheet material and process of manufacture. L. E. Barringer (General Electric Co.). U. S. 1,998,303, April 16, 1935 (Dec. 3, 1926; Oct. 26, 1929). An article of manufacture comprises a flexible sheet material, a coating thereon comprising an alkyd resin, and particles of abrasive material imbedded in the coating.

Abrading machine. A. N. Emmons (Porter-Cable Machine Co.). U. S. 1,998,417, April 16, 1935 (Feb. 6, 1933).

Abrading tool. G. F. Taylor (General Electric Co.). U. S. 1,996,598, April 2, 1935 (April 23, 1929).

Abrasive. Karl Eisenmann and Karl Wolf (Unyte Corp.). U. S. 1,996,911, April 9, 1935 (March 18, 1933); April 24, 1933).

Abrasive article and method of manufacturing. C. S. Nelson and D. B. Sharpe (Carborundum Co.). U. S. 1,995,321, March 26, 1935 (July 27, 1932). The method is that of making rubber-bonded abrasive articles.

Abrasive separating and cleaning apparatus. R. B. Huyett (Pangborn Corp.). U. S. 1,994,610, March 19, 1935 (May 22, 1930).

Abrasive wheel. C. E. Wilson (Independent Grinding Wheel Co., Inc.). U. S. 1,997,957, April 16, 1935 (Nov. 14, 1933). The process comprises preparing a moldable mixture of abrasive grains, calcined magnesite, argillaceous material, and magnesium chloride solution and molding the composition in a desired shape.

Device for dressing grinding wheels. Harry Hallam (United Shoe Machinery Corp.). U. S. 1,995,304, March 26, 1935 (April 21, 1932; May 29, 1934).

Drill grinder. Arthur Williams (A. L. Poinsette and L. J. Poinsette). U. S. 1,994,975, March 19, 1935 (April 20, 1931).

Flexible abrasive articles and processes of making. A. H. Stevens (Minnesota Mining & Mfg. Co.). Brit. 425,349 and 425,355, March 27, 1935 (June 7, 1933).

Flexible abrasive articles or sheets and process of making. A. H. Stevens (Minnesota Mining & Mfg. Co.). Brit. 425,298, 425,350, and 425,356, March 27, 1935 (June 7, 1933).

Grinding machine. Millard Romaine (Cincinnati Grinders, Inc.), U. S. 1,997,551, April 9, 1935 (Dec. 5, 1932). C. C. Stevens (General Motors Corp.), U. S. 1,996,842, April 9, 1935 (May 26, 1932).

Grinding and polishing machines. A. F. Kelm. Brit. 424,926, March 13, 1935 (April 26, 1934).

Grinding tool. Fred Glassford (Chrysler Corp.). U. S. 1,995,027, March 19, 1935 (April 22, 1932).

Internal grinding machines. Churchill Machine Tool Co., Ltd., and H. H. Asbridge. Brit. 424,261, March 6, 1935 (July 19, 1933).

Machine for dressing revolving grinding wheels. H. F. Atkins. U. S. 1,996,396, April 2, 1935 (Aug. 25, 1934).

Method of dressing grinding wheels. C. J. Halborg, W. A. Hart, and P. F. Seibold (Colonial Broach Co.). U. S. 1,997,862, April 16, 1935 (Dec. 9, 1932).

Polishing and grinding equipment. Deutsche Carborundum-Werke, G.m.b.H. Ger. 593,499, Nov. 1, 1932; *Keram. Rund.*, **42** [49] 613 (1934).—The equipment consists of oxides of the trivalent metals, Al_2O_3, Cr_2O_3, or Fe_2O_3, produced by precipitation and calcination of their hydroxides, and an organic binder, *e.g.*, a phenol-formaldehyde condensation product. A.K.

Process of grinding bearings. P. F. Hackethal (Aviation Mfg. Corp.). U. S. 1,997,903, April 16, 1935 (June 30, 1932).

Rotary abrading tool. H. F. Skillings (Blanchard Machine Co.). U. S. 1,996,980, April 9, 1935 (Aug. 16, 1933).

Two-slide automatic grinding machine. C. T. Raule. U. S. 1,997,978, April 16, 1935 (Oct. 7, 1926).

Valve grinding tool. L. O. Beard. U. S. 1,994,680,

[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

Abstracts from our abstracter in Czechoslovakia are sent to us through the Czechoslovak Ceramic Society, Praha XIX, 1417.

Art and Archeology

March 19, 1935 (May 11, 1934). J. J. DROHAN (George Erickson), U. S. 1,994,986, March 19, 1935 (June 7, 1934).

Artistry in European glasses. VIRGINIA HAMMILL. *Ceram. Ind.*, **24** [4] 220–21 (1935).—Decorative glass depends mostly on form for its appeal. Clear crystal and color in deep subtle off-tones are used. "Sculptured" glass and table decorations in the form of crystal balls, triangles, blocks, and columns of solid glass are new developments. There is a trend toward utilitarian pieces. Illustrated. E.J.V.

Ceramic art institute at Faenza. A. GRANGER. *Céram. Verrerie, Émail.*, **2** [6] 271–75 (1934).—The Museum of Ceramic Art at Faenza was founded in 1908 at the close of the Exposition of Art of Rome and the Exposition of Torricelli. It is today a clearing house for ceramic art and industry. Its collections include 6000 classic Italian majolica pieces, 5000 Oriental and Egyptian pieces, a collection of old ceramic art of the Italian colonies, 4600 books on ceramic art and industry, and 5000 photographs of public and private collections of antique pieces. A school of ceramics is maintained at the Museum. Illustrated. M.H.B.

Color analysis and specification. JOSEPH RAZEK. *Paper Ind.*, **16**, 171–73, 407–409 (1934).—The interpretation of the curve of reflectance against wave-length as obtained with the Razek-Mulder color analyzer is explained. (*C.A.*)

Coloring oxides. L. VIELHABER. *Emailwaren-Ind.*, **12** [3] 19–22 (1935).—The effect of various oxides on the color tone and the production of blues, greens, red, fire-red, brown, violet, yellow, black, wine-red, and gray colors are discussed in detail. M.V.C.

History of ring pitchers and canteens. MICHAEL BIRKENBIHL. *Keram. Rund.*, **42** [50] 621–22 (1934).—B. traces the development of these types of ceramic ware in ancient and medieval times. Illustrated. A.K.

Industry's attitude toward art training. FREDERICK H. RHEAD. *Bull. Amer. Ceram. Soc.*, **14** [4] 142 (1935).

Neutral value scales. II. Comparison of results and equations describing value scales. I. H. GODLOVE. *Jour. Opt. Soc. Amer.*, **23** [12] 419–25 (1933).—The equations proposed for the relation between value and reflection are examined. A new empirical equation containing the reflectance of the background and one arbitrary constant fits the Munsell data. For Part I see *Ceram. Abs.*, **13** [10] 248 (1934). R.H.H.P., JR.

Old English china revived. W. R. STOREY. *New York Times Mag.*, p. 14 (March 10, 1935).—Old English china, including Staffordshire products, porcelain Chelsea figurines, Bow, Lowestoft, Wedgwood, Mason's ironstone china, stone china, and Spode's earthenware, is briefly discussed. M.V.C.

Persian pottery of ancient times. GEORGE W. BRAINERD. *Bull. Amer. Ceram. Soc.*, **14** [4] 156 (1935).

Unifying the hand crafts. W. R. STOREY. *New York Times Mag.*, p. 15 (April 7, 1935).—The exhibition of the Keramic Society and Design Guild is described. Figurines of old English salt-glazed stoneware, a product of the Staffordshire district, were made mostly between 1730 and 1770. A large collection is in the Metropolitan Museum, N. Y. M.V.C.

BOOKS

Ancient Egyptian materials and industries. A. LUCAS. 2d ed. revised. xii + 447 pp. Edward Arnold and Co., London, 1934. Price 16s net. Briefly reviewed in *Nature*, **135** [3411] 416 (1935).—Among the industries treated are faience and glassmaking, metal working, pottery making, and stone working. Chemical analyses of materials are included in an appendix. J.L.G.

Technical and artistic finishing of porcelain and faience. P. N. MUSSIVENKO. Edited by A. I. Kramarenko. Ukrain. State Pub. House of Light Industry, Kharkov, 1934. 59 pp., 22 figs. Price 2R. The following headings furnish a summary of the contents: (1) work with the aërograph, (2) finishing with decalcomania, (3) figures on porcelain and faience (underglaze and overglaze with compositions of the colors used and methods of their application), (4) hand painting, (5) firing overglaze colors in a muffle, (6) characteristic of ceramic colors. Written in the light of practical experience in a faience plant, the book seems to be a useful contribution to the subject. The book is well printed. S. I. PERKAL

PATENTS

Continuous method of applying glass spheres or particles to flat surfaces. J. D. MCBURNEY AND E. H. NOLLAU (E. I. du Pont de Nemours & Co.). U. S. 1,998,053, April 16, 1935 (Nov. 8, 1930; June 5, 1934).

Decalcomania and method of making. J. F. MCNUTT (American Decal Corp.). U. S. 1,996,549, April 2, 1935 (Nov. 30, 1934).

Designs for:

Bottle. A. L. KEY (Hazel-Atlas Glass Co.), U. S. 95,262, April 16, 1935 (Feb. 13, 1935). W. A. NESTER (Obear-Nester Glass Co.), U. S. 94,921, March 19, 1935 (Jan. 9, 1935).

Ceramic wall bracket for electric lighting. R. G. COWAN (Pass & Seymour, Inc.). U. S. 95,227, April 16, 1935 (Dec. 21, 1934).

Cooking range. SAMUEL KLUTE (Malleable Steel Range Mfg. Co.). U. S. 95,267 and 95,268, April 16, 1935 (Feb. 6, 1935).

Cream pitcher. VIKTOR SCHRECKENGOST (Limoges China Co.). U. S. 95,152, April 9, 1935 (Jan. 25, 1935).

Cup. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,915, March 19, 1935 (Jan. 3, 1935).

Electric lighting fixture. R. G. COWAN (Pass & Seymour, Inc.). U. S. 95,226, April 16, 1935 (Dec. 21, 1934).

Jar. B. D. FUERST (Owens-Illinois Glass Co.). U. S. 95,240, April 16, 1935 (Feb. 11, 1935). O. C. NOBLE (Tygart Valley Glass Co.). U. S. 94,984, March 26, 1935 (Jan. 21, 1935).

Jug, etc. J. M. GAYNER (Gayner Glass Works). U. S. 95,035, April 2, 1935 (Jan. 15, 1935).

Lamp chimney. T. F. MCBRIDE. U. S. 94,919, March 19, 1935 (July 27, 1934).

Pitcher. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,909, March 19, 1935 (Jan. 3, 1935).

Plate. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,911, March 19, 1935 (Jan. 3, 1935). GEORGE WESP (Continental Ceramics Corp.). U. S. 95,165 and 95,166, April 9, 1935 (Jan. 19, 1935).

Platter. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,913, March 19, 1935 (Jan. 3, 1935).

Saucer. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,914, March 19, 1935 (Jan. 3, 1935).

Sugar bowl. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,910, March 19, 1935 (Jan. 3, 1935).

Teapot, etc. BELLE KOGAN (Ebeling & Reuss, Inc.). U. S. 94,912, March 19, 1935 (Jan. 3, 1935).

Machine for continuously applying glass spheres or particles to flat surfaces. J. D. MCBURNEY AND E. H. NOLLAU (E. I. du Pont de Nemours & Co.). U. S. 1,998,055, April 16, 1935 (Nov. 8, 1930; July 19, 1934).

Cements

Calcium aluminates and their significance in cement. GUNNAR ASSARSSON. *Zement*, **23**, 1–3, 15–20 (1934).—A comprehensive study is made of the phase relations in the system CaO–Al_2O_3–H_2O, with the results shown graphically. The chief crystalline products formed are $4CaO \cdot Al_2O_3 \cdot 10.5H_2O$, $3CaO \cdot Al_2O_3 \cdot 12H_2O$, $2CaO \cdot Al_2O_3 \cdot 9H_2O$, $Al_2O_3 \cdot 4H_2O$, and $Ca(OH)_2$. The crystallization processes are aided by increase in temperature and retarded by decrease in the amount of mixing water. The main product of the hydration of $CaO \cdot Al_2O_3$ is a gel of index 1.53 accompanied by crystals of $2CaO \cdot Al_2O_3 \cdot 9H_2O$. The hydration products of $3CaO \cdot 5Al_2O_3$ are similar. Aluminous cements when shaken with 0.4 to 20 parts of water show solution only for about an hour, with precipitation occurring rapidly after the second hour. The ratio of CaO to Al_2O_3 is highest in the more dilute solutions. See also *Ceram. Abs.*, **14** [1] 21–22 (1935). (*C.A.*)

Clay of Portland cement. XX. Iron oxide of high alumina Portland cement; mixing proportion, grinding, and clinkering of the raw mixture and the testing of the clinker. YOSIAKI SANADA. *Jour. Soc. Chem. Ind.* [Japan], **38** [1] 12–14*B* (1935).—Data on the tests made are tabulated and conclusions are given. M.V.C.

Differentiation of energetic relationships between the hydration products of the compounds present in the 3-component system CaO–Al_2O_3–SiO_2 and the properties of Portland cement. OTTO FR. HONUS. *Zprávy Ceskoslov. keram. spolecnosti*, **10** [1–2] 31–42 (1933); abstracted in *Tonind.-Ztg.*, **58** [43] 522 (1934); *Sprechsaal*, **67** [30] 452 (1934).—The thermochemical processes occurring during the hydration of compounds found in the 3-component system CaO–Al_2O_3–SiO_2 and the relationship between the heat of hydration and the physical properties of technical Portland cement were studied. M.V.C.

Italian cement standards. HANS R. DEWIDELS. *Zement*, **22**, 717–18 (1933). (*C.A.*)

PATENTS

Dental cement. HEINRICH HERZOG. Fr. 765,693, June 14, 1934. A composition for filling teeth or making artificial teeth is formed of a cellulose derivative, preferably an ester such as nitrocellulose, inorganic substances (salts such as Ca phosphate, carbonate, or silicate), and a volatile organic solvent (acetone). Softening agents (camphor) or hardening agents (resins) and pigments may also be present. (*C.A.*)

Process of hardening plaster or other porous ware. B. SZEPS. Brit. 425,742, April 3, 1935 (July 26, 1934).

Enamels

Defects in enameling. ANON. *Glashütte*, **64** [48] 791–93 (1934).—A discussion of the causes of defects in enameling, some of which are the result of recent changes and modernization of the process, is given. See also *Ceram. Abs.*, **14** [5] 108 (1935). M.V.C.

Degree of fatigue and recovery therefrom of carbon steels under repeated impacts. F. ÔSHIBA. *Sci. Repts. Tohoku Imp. Univ.*, **23** [4] 589–611 (1934).—Various Swedish steels were tested. The degree of fatigue was found to progress at three rates as the number of blows increases. It progresses slowly, then very rapidly, and finally slowly again, until the specimen breaks down, the duration of each stage being affected by the stress due to impact and by the shape of the specimen. Higher carbon content of the steel results in a greater degree of fatigue in the earlier stage of impacts and in a smaller degree in the later stage. Some recovery from fatigue by annealing takes place throughout the various stages, but the recovery between the second and third stages of impacts is most conspicuous. The degree of fatigue and the fatigue crack are closely related to each other. W.M.C.

Enamel art in Cleveland. H. EDWARD WINTER. *Enamelist*, **12** [6] 20–21 (1935).—Cleveland is using porcelain enamel for modern buildings, decorative arts, and utilitarian products, from jewelry, vases, and plaques to great murals. The work of Winter in murals, done in a modern enameling plant, is described. E.J.V.

Enameler's dream. J. F. ROCHE, JR. *Enamelist*, **12** [6] 7 (1935).—The new porcelain enameling plant of the Edison General Electric Appliance Co., Chicago, is of the latest and most efficient design. Illustrated. E.J.V.

Enameling cast-iron apparatus and containers for the chemical industry. ANON. *Glashütte*, **64** [46] 759–62 (1934).—The following points are briefly discussed: (1) the cast iron, (2) preparation for enameling, (3) ground enamel, (4) coat and powder enamel, (5) apparatus and application, (6) laboratory tests, (7) electrical testing, and (8) reënameling. M.V.C.

Enamel shop control. E. C. AYDELOTT AND W. H. PFEIFFER. *Better Enameling*, **6** [3] 12–17 (1935).—This paper discusses problems due to some extent to a change in product design and how these problems can be successfully met. Illustrated. E.J.V.

Enamel shop prevents contamination of air and fouling of ducts and reclaims enamel. EDISON GENERAL ELECTRIC APPLIANCE CO. *Heating, Piping & Air Conditioning*, **7** [2] 95–96 (1935).—Baffle plates (with holes) placed

in the back of spray booths reclaim the largest portion of the sprayed material. Enamel which passes the baffle plates in the exhaust air is reclaimed by a two-stage water spray. This recovers about 97 to 98% of the enamel sprayed into the booths. It prevents the contamination of the air around the plant and the fouling of exhaust fans and ducts thus preventing any lowering of their efficiency of operation. Exhaust hoods are also located above the dusting tables where the rimming operations are performed by wire brushes. J.L.G.

Formation of cracks in steel during heat treatment. E. SCHEIL. *Arch. Eisenhüttenwesen*, **8**, 309–14 (1934).—The location of a crack in the steel makes it possible to trace the temperature of its origin. In most cases, cracks will form only after the last change of strain has taken place close to room temperature. Cracks will often form below the static breaking strength of the steel. Visible cracks may originate from minute cracks which can be detected only by means of the microscope. Such microcracks may even form some time after cooling the sample; their number decreases with a small amount of tempering. W.M.C.

Glaze and enamel. WALTER OBST. *Seifensieder-Ztg.*, **61**, 545 (1934).—Ceramic glazes and baked enamels having a varnish base are briefly compared, and the advantages of using artificial resins in preparing such enamels are emphasized. (*C.A.*)

Hommelaya process of enameling. J. E. ROSENBERG AND W. J. BALDWIN. *Ceram. Ind.*, **24** [4] 225–27 (1935).—By dipping the prepared steel in a solution which deposits on the iron a compound of steel, a white opaque frit can be applied as a combination of a ground coat and a cover coat in one fire. On this first coat may be applied subsequent layers of enamel. Ware produced has greater resistance to thermal and mechanical shock. E.J.V.

Manufacture and enameling of pipes. RENIER. *Glashütte*, **64** [47] 777–78; [48] 794–96 (1934).—A detailed account is given of the manufacture of the pipes, the application of the ground enamel by immersion, spraying the final coat, drying, firing, etc. M.V.C.

Manufacturing porcelain enamels. CHICAGO VITREOUS ENAMEL PRODUCT CO. *Better Enameling*, **6** [3] 23–26 (1935).—A description of the steps involved in manufacturing porcelain enamel from the raw materials to the finished, iron-free, dry frit is given. Illustrated. E.J.V.

Mechanics of enamel suspension. I. Exchangeable base and viscosity measurements on Vallendar clays. G. E. TERRY AND R. M. KING. *Jour. Amer. Ceram. Soc.*, **18** [5] 141–44 (1935).

Porcelain enamel industry in 1934. EMERSON P. POSTE. *Ceram. Ind.*, **24** [4] 230–34 (1935).—In this review of the developments in porcelain enamel work during 1934, P. takes up fundamentals, raw materials, uses of raw materials, and enamel composition. E.J.V.

Rôle of enameled earthen pots in causing lead poisoning. BÉLA PURJESZ. *Orvosi Hetilap*, **78**, 905–906 (1934).—Forty pot samples of 36 peasant manufacturers in the country were examined for soluble Pb content of the used enamels by means of KI and $K_2Cr_2O_7$. Seven samples contained much Pb, 13 samples traces only. The obligatory use of so-called fritted enamels consisting of insoluble Pb silicates is recommended. (*C.A.*)

World's largest continuous porcelain enameling furnace. FERRO ENAMEL CORPORATION. *Enamelist*, **12** [6] 8–9 (1935).—The new "U" or "hairpin" type continuous furnace in the Leonard Plant of the Kelvinator Corporation at Grand Rapids, Mich., has an overall length of 88 ft., exclusive of 65 ft. of conveyer extension. The nine burners cross-fired are the first installation using propane as fuel. Details of construction and operation are given. Illustrated. E.J.V.

BOOK

Mechanical working of sheet iron: stamping, annealing, metal plating, enameling, decorating (Travail mécanique des toles: emboutissage, recuit, etamerie, emaillerie, decoration). J. NAPPÉE. Ch. Beranger, Liége. 415 pp. 150 Belgian F. Reviewed in *Verre & Silicates Ind.*, **6** [4] 72 (1935).—This book deals with the practical work connected with the working of sheet iron. It is in two parts: (1) working the raw materials, and (2) finishing. The part dealing with enameling is treated in a detailed and interesting manner. M.V.C.

PATENTS

Cooking range and stove. JACOB TELLER AND A. P. SCHULZ (Teller Stove Designing Corp.). U. S. 1,998,343, April 16, 1935 (Dec. 17, 1931).

Enamel. IGNAZ KREIDL. Ger. 580,570, July 13, 1933. White enamel rendered turbid by gas is applied to objects by admixing materials which evolve H during firing. Thus, an enamel mass may be given an addition of Zn, clay, and water. The Zn may be replaced by other metals or metalloids such as Si, which evolve H with water. (*C.A.*)

Enamel. IGNAZ KREIDL. Ger. 601,992, Aug. 29, 1934. In making white enameled Fe, turbidity is produced by a substance giving off gas at the fusion temperature, *e.g.*, $(CO_2NH_4)_2$, in addition to the usual white oxide such as nO_2. (*C.A.*)

Material for and process of pickling and cleaning. A. E. CHESTER (Ferro Enamel Corp.). U. S. 1,995,766, March 26, 1935 (June 1, 1934).

Process of enameling metal articles. H. F. STALEY. U. S. 1,996,840, April 9, 1935 (May 24, 1932). In the enameling of metal articles, the naked article is heated to enamel-fusing temperature in a furnace having a non-oxidizing atmosphere, and a coating of vitrifiable dry enamel powder is applied to the heated naked article in the furnace, while the furnace is kept at the temperature and the non-oxidizing atmosphere maintained.

Process of making vitreous enamel coated sheets. J. C. ECKEL. U. S. 1,998,045, April 16, 1935 (Nov. 21, 1933). The method of producing a vitreous enameled coated steel sheet having a quality and surface free from boiling defects consists in reducing a sheet of low carbon steel an amount so as to leave at least a 30% reduction necessary to produce the finished gage, then reducing the sheet to the finished gage by cold rolling, and finally applying and firing the vitreous enamel coating thereon.

Tiled construction. Z. C. WILKINSON (Porcelain Tile Corp.). U. S. 1,997,399, April 9, 1935 (Aug. 5, 1932).

Glass

Apparatus for making glass instruments for micromanipulations. P. DE FONBRUNE. *Compt. rend.*, **195**, 706–707 (Oct. 24, 1932).—The production of glass needles and pipets for very minute work is quite difficult if attempted by ordinary methods. F. describes apparatus which makes such instruments easily and accurately. A minute platinum wire, electrically heated, forms the source of heat. A small but controllable air blast is provided just to one side of this platinum filament. Mechanical means are provided for moving the glass work independently of the filament and air blast. The whole is readily made small enough to go on an ordinary microscope stage. The glass is heated by the incandescent filament and drawn into shape, being cooled rapidly by the air blast as it leaves the source of heat. F. gives a rough set of directions for producing capillary tubes of the order of one micron and several centimeters long as well as micropipets, the diameter of whose extremities will be a fraction of a micron only. (*R.S.I.*)

Blast-furnace slags in glassmaking. ANON. *Glass Ind.*, **16** [3] 84 (1935).—The work of Bisor, Basore, Althof, and Kitaigorodskiĭ and Karev (see *Ceram. Abs.* Author Indexes, 1930–1934) on the availability of blast-furnace slags as glass constituents is briefly reviewed. By adjusting the glass constituents to compensate for the lack of certain oxides in the slag it is possible to produce colored glass. Use of slags as colorants is also indicated. E.J.V.

Boots and boot tanks. FRITZ ALTHOF. *Glashütte*, **65** [4] 55–57 (1935).—The construction of a new "double boot" for removing glass from tank furnaces, which avoids soiling the glass in the boot, is given in detail. The installation of the boot, ascertaining the proper size and depth of immersion, and converting a day tank so that it will operate continuously and thus increase production while the quality of the glass remains completely satisfactory are explained fully. M.V.C.

Colored coatings on glass. ANON. *Glashütte*, **64** [49] 808 (1934).—Covering glasses entirely or partially with a colored coating in a single firing consists in annealing copper compounds alone, or in combination with other metals, on sulfide glasses (especially black) free from carbon. A batch of a black sulfide glass is given. See also "Coloring—" *Ceram. Abs.*, **14** [2] 29 (1935). M.V.C.

Comparative study of the refining of ordinary and crystal glass. A. THOUVENIN. *Céram., Verrerie, Émail.*, **2** [4] 155–60 (1934).—T. calculates the rate of rise of the bubbles in ordinary and crystal glass. Working time for crystal glass is 16 hr., for ordinary glass, 4 hr. Refining materials such as arsenious anhydride, sodium nitrate, etc., reduce the working time and produce a glass free from bubbles. *Ibid.*, **2** [10] 433–36 (1934).—In searching for an explanation of the longer working time for crystal than for window glass, T. developed the following formula:

$$\frac{D \text{ common}}{D \text{ crystal}} = \sqrt[3]{\frac{\Sigma\,\eta \text{ crystal}}{\Sigma\,\eta \text{ common}}}$$

where D = bubble diameter, η = viscosity. Results obtained with this formula are in accord with practice, giving a calculated ratio of 1:3.89 as to 4:16 for common and crystal glass, respectively. M.H.B.

Constitution of colored glasses. W. WEYL. *Ind. Ver.*, **1**, 107–10 (1934).—In chrome glasses the equilibrium between trivalent chromium and hexavalent chromium plays an important rôle, but the equilibrium between the basic and acidic constituents depends upon the base glass. The absorption spectrum for vitreous metaphosphoric acid (with no basic constituent) resembles that given by a soda-silica glass colored with chromium, though chromium glasses show a shift of the absorption bands toward the longer wave-lengths, in the opposite direction to aqueous solutions of chromium salts. In aventurine chrome glasses, green metallic plates of Cr_2O_3 separate out and are so oriented as to lie parallel to the glass surface. The coloration in cobalt glasses varies considerably with the base glass, a potash-silica base giving a blue, a phosphate base a reddish, and a boric oxide base glass a violet color, although the cobalt is divalent in each case, indicating that the color is not dependent on the state of oxidation of the cobalt. Using aqueous cobalt chloride solutions, three types of color can be obtained: the first by a dilute CoCl solution, with a maximum in the green (in the absorption spectrum), the second, blue color corresponding to a nonsaturated cobalt ion, obtainable in stronger solutions, and third, an intermediate, crystalline combination of cobalt being capable of realization in glasses and in solutions. See also *Ceram. Abs.*, **14** [1] 7 (1935). (*J.S.G.T.*)

Defects produced by stones in glass. HERBERT INSLEY. *Glass Ind.*, **16** [3] 79–80 (1935).—"Stones" in glass give rise to other defects besides the unsightliness which usually causes the rejection of the ware containing the stones. The thermal expansions of the crystals commonly found in stones and of glass are compared. The need for qualitative correlations of the type of stone with the amount of breakage caused by the stone and with the presence or absence of associated cords and lumps is indicated. E.J.V.

Determining the refractive index of vitreous silica and the calibration of silica refraction thermometers between 18 and −200°C. J. B. AUSTIN AND R. H. H. PIERCE, JR. *Physics*, **6** [1] 43–46 (1935).—The variation with temperature of the refractive index of fused silica for the helium line 5877.2 Å has been determined between 18 and −200°C, and the results have been applied to the calibration of vitreous silica refraction thermometers at low temperatures. These data have been correlated with measurements at high temperatures. It is found that the refractive index between −200 and 1000°C can be represented by the equation $n = 1.45657 + 0.001553\, t/100 + 0.00219\, e^{-0.33t/100}$.

Didymium in eyeglasses. A. POLACK. *Compt. rend.*, **200** [6] 488–90 (1935).—According to the recognized theories of vision (Helmholtz, Newton) and of the physiology of the eye, the yellow colors are the most important in forming the object in the eye. Recently it was found that didymium (a mixture of neodymium, praseodymium, and cerium used in optical glasses for the absorption of the harmful ultra-violet rays) absorbs also yellow radiations

and puts a heavy strain on the eye. It is better to use glasses containing cerium only which is purified of neodymium and praseodymium but yet protects the eye from ultra-violet rays. M.H.

Effect of water-vapor on rate of reactions in glass manufacture. J. A. JOFFE AND A. A. SCHAKINA. *Compt. rend. acad. sci. U.S.S.R.*, **3**, 516–22 (1934).—The rate of glass formation of the glass SiO_2 73, Na_2O 16, and CaO 11% was studied over the range 600 to 900° in the presence of water-vapor at pressures of 3 to 10 atmospheres. Melting in the presence of water-vapor produced a greater loss in weight, and the silicates formed were stated to be more stable than in the absence of water. The reaction between the components of the glass was in all cases accelerated. (*J.S.G.T.*)

Glassmaking in Britain 100 years ago. H. W. LEE. *Glass Ind.*, **16** [4] 116–18 (1935).—A brief historical sketch of the types of furnaces and operations used in Britain 100 years ago in making bottle, crown, sheet, flint, optical, and cast plate glass is given. Illustrated. E.J.V.

Glassmelting in a vacuum. O. K. BOTVINKIN. *Keram. i Steklo*, **11** [1] 32–33 (1935).—Glassmelting in a vacuum and attempts to do this in U.S.S.R. are briefly discussed. Experiments to determine the effect of a vacuum on the rate of degasification of the glass mass are described. It was found that a vacuum greatly increases the rate of degasification and of dissolving of the glass mass. At a pressure of 150 mm. Hg the glass was melted twice as rapidly as with normal pressure. Difficulties in melting were encountered at pressures of 50 and 25 mm. Hg because of the pressure of soda vapors at high temperature, changes in the glass mass composition, and scorification of refractories. M.V.C.

Glass-to-metal seals. ALBERT W. HULL AND E. E. BURGER. *Physics*, **5** [12] 384–405 (1934).—The problems of sealing are adhesion and strain. The simplest means of adhesion is a firm layer of metal oxide. Strains can be avoided if the thermal expansions of metal and glass are the same. This postulate is thoroughly tested. Equations are derived for the stresses in cylindrical seals in terms of the difference in expansion of metal and glass, and the stresses thus calculated are compared with those observed photoelastically in carefully annealed test seals. Such tests are carried out on all the important sealing materials. These tests include accurate contraction coefficient measurements of glass and metals, graphical exhibition of axial stresses by photographs through crossed nicols and a quartz wedge, and numerical evaluation of all the stresses, both theoretical and experimental. Two new sealing alloys are described; Fernichrome (Fe 37, Ni 30, Co 25, Cr 8%) which matches standard lead glass, and Fernico (Fe 54, Ni 28, Co 18%) which matches Corning glasses G-71 and G-705 A O. The unique feature of these alloys is that their expansion characteristics are curved in such a manner that they match those of the glasses mentioned with considerable fidelity. The seals made with these combinations are found to be practically free from strain. See also "Metal-to-glass—" *Ceram. Abs.*, **14** [1] 9 (1935).

Glass thickness viewer. C. F. SMITH. *Glass*, **12** [2] 57 (1935).—The apparatus measures the thickness of glass working from only one side of the glass. The glass article is placed at one end of the instrument, and two dark lines are formed on the screen at the other end. The separation of these lines, measured on the instrument's scale, represents the thickness of the glass. Thicknesses up to 6 mm. (within 0.25 mm. on the scale and by estimation to 0.04 mm.) may be measured. Also in *Engineering*, **139**, 31 (1935). M.C.S.

History of the York school of glass-painting. XII (continued). J. A. KNOWLES. *Jour. Brit. Soc. Master Glass-Painters*, **5**, 187–95 (1933–1934).—Political allusions in York work, including signs and tokens of the loyalty of parishioners and their pride in their native city and country are described. In the tracery of York windows suns and stars, frequently shown one on either side, are explained. Lions and eagles, used in conjunction, are another common feature of York glass. Illustrated. See *Ceram. Abs.*, **14** [2] 29 (1935). (*J.S.G.T.*)

Improvement in regenerative furnaces. W. A. MORTON. *Glass Ind.*, **16** [4] 107–108 (1935).—In using regenerators in high-temperature furnaces fluxes often react with the checker brick in such a way as to clog the checkers and impair the efficiency. A hollow wall built around the checkers makes it possible to by-pass air to the furnace without heat losses; at the same time it becomes an efficient, low-cost, insulated type of wall. Another recent improvement involves the use of a smaller than conventional regenerator where raw producer gas is used, which not only avoids "cracking" the hydrocarbons in the gas but also reduces the quantity of fuel lost during reversals of the furnace. The life of all parts of the furnace must be balanced to insure uninterrupted performance at maximum rating. Illustrated. E.J.V.

Index of refraction, density, and thermal expansion of some soda-alumina-silica glasses as functions of the composition. CONRAD A. FAICK, JOHN C. YOUNG, DONALD HUBBARD, AND ALFRED N. FINN. *Jour. Research Nat. Bur. Stand.*, **14** [2] 133–37 (1935); R.P. 762. Price 5¢; *Glass Ind.*, **16** [3] 81–83 (1935).—The index of refraction and density of 44 soda-alumina-silica glasses and the thermal expansions of 29 of the glasses were determined. The composition of the glasses, which varied from 1 to 10% alumina, 19 to 45% soda, and 50 to 78% silica, was determined by chemical analyses. The data are given in tabular form and graphs are presented from which the index of refraction, density, critical softening temperatures, and the linear thermal expansion from room temperature to these temperatures can be predicted with reasonable accuracy for any glass in the series studied. The substitution of alumina for soda and silica in the proper ratios will give glasses having the same refractivity, density, and expansion as the original soda-silica glass; these ratios are approximately 1:1.8, 1:1, and 1:1.5, respectively. On the expansivity for a given temperature range the effect is about the same as that of silica. R.A.H.

Lippert, new master of German art glass. OTTO KLETZL. *Glashütte*, **64** [46] 752–54 (1934).—The background, new technique, and artistic contributions of Oswald Lippert are discussed. Illustrated. M.V.C.

Mechanical batch handling profits Glass Containers, Inc. JOHN M. COOPER. *Glass Ind.*, **16** [3] 73–77 (1935).—

The new plant for Glass Containers, Inc., in Los Angeles, Calif., has the following features: (1) a batch handling plant as automatic as possible and operated from a central point; (2) all sand handled wet; (3) automatic, highly adjustable feeding of the batch to the furnace; (4) batch handling equipment of long life, as noiseless and dustproof as possible, and assuring no demixing; (5) a plant which may be expanded to three times original capacity at small cost and, when expanded, can handle two grades of sand and three or more kinds of cullet; (6) labor saving sorting and packing equipment at the discharge end of the leers; (7) automatic, recorded weighing of batch materials; (8) minimum set cost per ton for handling all batch materials from the cars to the tank. How these features were incorporated and the savings resulting from them are described. Illustrated. E.J.V.

Monochromatic green filter. B. LYOT. *Compt. rend.*, **200** [9] 738–39 (1935).—Neodymium glass has a wide and intense absorption in the yellow. A 50 mm. thick neodymium glass in conjunction with a 2 mm. Schott VG3 glass has a maximum transparency of 36% for wave 5600 Å over a width of 116 Å. A chart gives the absorption ranges for several combinations of glasses. M.H.

Old English glass. No. 57. FRANCIS BUCKLEY. *Glass*, **11** [12] 474 (1934). **No. 58.** *Ibid.*, **12** [2] 74 (1935).—B. describes the crude furnaces and working tools used in making glass articles in England about 1754. For No. 56 see *Ceram. Abs.*, **14** [4] 86 (1935). M.C.S.

Problem of malleable glass. JAMES BAILEY. *Bull. Amer. Ceram. Soc.*, **14** [4] 152–55 (1935).

Production and properties of beryllium fluoride glasses. A. SALMONY. *Sklarske Rozhledy*, **11**, 35–37 (1934).—When melting BeF with alkalis or alkaline earth fluorides, glasses are obtained whose specific properties are important for special cases. Directions for the production of glasses from BeF_2 with NaF, KF, MgF_2, CaF_2, AlF_3, and CoF_3 are given. These glasses are unstable to water and weather in air; their softening temperatures lie between 160° and 280°; they have a high coefficient of expansion, and hence can not be fused with other glasses. They have a very high permeability to ultra-violet rays, similar to that of quartz. M.V.C.

Progress of the glass industry in 1933. III. OSCAR KNAPP. *Glashütte*, **65** [6] 70–82 (1935).—This paper is a brief discussion dealing with (1) the dependence of the reaction velocity in sand-soda batches on the grain size of sand, (2) use of dust-like sand for glass melting, (3) economy and output of tank furnaces, (4) obtaining window glass with electric heat, (5) physical and chemical processes occurring when melting sand, minium, and potash, (6) melting process of soda-alkaline earth glass, (7) studies on stones and cords in glass, (8) defects occurring in the Fourcault method, (9) gas in glass, (10) refining effect of antimony oxide, (11) stratification of homogeneous glass melts, (12) cooling glass, (13) working glass with metal, (14) special glass, (15) life period of glass tanks, (16) production of Corhart brick, (17) calculation of the resistance to temperature changes of refractories and their physical constants, (18) principles of chemical analysis of glass, (19) rapid determination of silica in silicates, (20) determination of lead in the presence of bismuth and barium, (21) determination of boric acid in glasses free from arsenic and fluorine, (22) determination of sodium oxide, and (23) analysis of gas content in glass. For Part II see *Ceram. Abs.*, **14** [5] 111 (1935). M.V.C.

Quantitative crystalline analysis by means of X-rays. M. E. NAHMIAS. *Z. Krist.*, **85**, 319–21 (1933).—This is an addendum to a previous article (*Ceram. Abs.*, **12** [3] 124 (1933)). (*C.A.*)

Rapid analysis of soda-lime glasses and its use for potash glasses. Supplement. A. NOEL. *Ing. Chim.*, **22** [103] 3–6 (1934); abstracted in *Sprechsaal*, **68** [9] 135 (1935).—As the alkalis often contain small quantities of lime salt, the following method was perfected. The residue from the sulfide-hydrofluoric acid treatment is dissolved with warm water and transferred into an Erlenmeyer flask (500 to 700 cc.). It is then diluted with water to 300 to 350 cc.; 1 cc. maximum "perhydrol" and 250 cc. *N*/2 sodium carbonate solution are added. This is boiled 30 min., 0.25 g. ammonium oxalate is added, and it is again boiled 15 min. After cooling, it is filtered through a double filter and washed with cold ammonium oxalate solution (0.25 g. salt/l.) until the disappearance of the sulfate reaction. The alkalis are then determined in the usual way. After weighing, it is dissolved in dilute HCl and transferred into a 500 cc. flask; 1 g. ammonium chloride is added, and the boiling solution is precipitated with a very small excess of ammoniac (methyl red). With this operation, small traces of aluminum, which were in the alkali as Na-aluminate, are removed. This method can also be used for potash lime glasses. See also "Complementary—" *Ceram. Abs.*, **13** [7] 193 (1934). M.V.C.

Sodium-light lamp and its use. A. SALMONY. *Sklarske Rozhledy*, p. 53 (1934).—In 1931 the Osram Company put a small sodium light bulb on the market; these bulbs are being produced in increasing extent. The glass used must be resistant to the alkali. Free silica is reduced by sodium and the glass becomes black. At 360°C the glass attains the maximal emission (6 *n*); it is nontransparent and behaves like an ideal black body. At $^1/_2$ *n* the glass is transparent but the emission is low. Where the transparency is not necessary, the bulb is coated with a silver film and thus the bulb may be heated to the same temperature using only $^1/_3$ of the energy needed to heat an uncoated bulb. See also *Ceram. Abs.*, **13** [8] 218 (1934). R.B.

Standardizing laboratory glassware. TH. FAIVRÈT. *Ann. chim. anal. chim. appl.*, **16**, 346–55 (1934).—Standardization of beakers, watch glasses, etc., is discussed. *Ibid.*, pp. 394–98 (1934).—Specifications in Russia, Germany, and Czechoslovakia for various flasks used in the laboratory are given. (*C.A.*)

Tank cooling by use of air. R. R. ROBINSON. *Bull. Amer. Ceram. Soc.*, **14** [4] 151 (1935).

Temperature of the transformation intervals of glasses formed from B_2O_3 with Na_2O and BaO. E. JENCKEL. *Z. Elektrochem.*, **40** [7*b*] 541 (1934).—The only factor known for finding the kind of molecules present in binary glasses of soda or barium oxide with boric oxide is the temperature of transformation. Such data as refractive index and density do not indicate the phase transformations. E.J.V.

Testing glass containers for chemical durability. W. E. S. TURNER. *Jour. Amer. Ceram. Soc.*, **18** [5] 135–41 (1935).

Thermal expansion of Jena thermometer glass 2954''' by the vertical comparator method, and down to 4°A by the interferometric method. W. H. KEESOM AND D. W. DOBORZYNSKI. *K. Onnes Laboratory, Leiden, Communication* No. 234 *a* and *b*; *Physica*, **1**, 1085–88, 1089–1102 (Oct.–Nov., 1934).—Thermal expansion of the Jena glass 2954''' used in a gas thermometer was measured down to −253° by the vertical comparator method introduced by Van Agt and K. Onnes. The following formula was valid from +100° to −273° : $l = l_0 [1 + \{ a\tau + b\tau^3 + c\tau^3 + d\tau^4 + e\tau^5 \} \times 10^{-6}]$, where $a = 545.89$, $b = 19.55$, $c = 17.16$, $d = 27.99$, $e = 5.24$, and $\tau = t/100$. Using the interferometric method of Fizeau-Abbé-Pulfrich, the thermal expansion coefficient was determined down to the temperature of liquid helium, measurements being both absolute and relative to fused quartz, good agreement existing between these results and the data obtained by the comparator method. Small differences in α existed between different samples, either dependent on conditions regarding annealing or wall thickness, or even independent from these. Both methods showed that the expansion coefficient of fused quartz decreases to 0 when approaching absolute zero. (*J.S.G.T.*)

Volcanic ash as a constituent of glass batches. F. W. PRESTON. *Glass Ind.*, **16** [4] 111 (1935).—While in Europe natural rock materials are used as constituents of the glass batch, little or no advantage is taken of such cheap natural glassforming materials in the U. S. Pumicite, a powdered volcanic ash, seems to have good possibilities in glassmaking. Its chemical analysis, excluding moisture and iron content, is very nearly like certain alumina silica glasses, except for low alkali content. Its high alumina content may offer possibilities as a source of alumina in colored glasses. Disadvantages seem to be that (1) use must be confined to plants close to the source; (2) its high iron content excludes use in glasses other than highly colored; (3) care must be taken to prevent large losses of pumicite from the batch due to its fine grain size and low density. Main advantages lie in the fact that very low cost glass can be produced. See also "Results—" *Ceram. Abs.*, **12** [4] 145 (1933); "Investigations—," *ibid.*, **13** [10] 272 (1934). E.J.V.

BOOK

Flat Glass (Flachglas). Edited by Marcello Pirani and Karl Quasebart. Das Glas in Einzeldarstellungen, Vol. 8. 168 pp. Published by Akademische Verlagsgesellschaft m.b.H., Leipzig, 1934. Price 12 M bound, 11 M unbound. **Sheet glass.** WALTER KÖNIG. K. gives detailed and precise information on three methods of working used at present in the manufacture of sheet glass: (1) Fourcault, (2) Libbey-Owens, and (3) Pittsburgh. For each method, complete characteristics as to the particular properties of the glasses, capacity of production, and working are given. **Cast glass.** RUDOLF SIMON. Various kinds of cast glass and wire glass are discussed in detail. Different methods used at present for their production are compared, and the latest patent literature on these glasses is dealt with. **Plate glass.** LAMBERT VON REIS. The development of the plate glass industry is described in detail. The composition, properties, and requirements of plate glass, the production of pots for casting plate glass, and their composition are dealt with. Special attention is paid to the Bicheroux method, and the development of continuous methods of fine grinding and polishing plate glass is discussed. M. V. CONDOIDE

PATENTS

Apparatus for:

Circulating molten glass. A. G. LAUCK (Owens-Illinois Glass Co.). U. S. 1,995,391, March 26, 1935 (Dec. 19, 1932).

Cooling glass. CORNING GLASS WORKS. Fr. 774,475, Dec. 7, 1934. (*C.A.*)

Making glass and slag wool. N. V. MAATSCHAPPIJ TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Fr. 43,484, June 7, 1934. Addition to Fr. 726,355, Nov. 18, 1931. (*C.A.*)

Rolling glass. N. V. MAATSCHAPPIJ TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Fr. 773,814, Nov. 26, 1934. (*C.A.*)

Tempering glass. SOC. ASSUREX. Fr. 774,474, Dec. 7, 1934. (*C.A.*)

Tempering glass objects. SOC. ANON. DES GLACERIES ET CHARBONNAGES DE BOHÊME, ANCIENNE FIRME ANDREAS ZIEGLER'S SOHN. Fr. 765,339, June 8, 1934. (*C.A.*)

Transporting sheets of glass. GLACERIES DE LA SAMBRE SOC. ANON. Brit. 425,514, March 27, 1935 (Oct. 2, 1933).

Working glass, etc. ZOLTÁN VERESS, JR., AND EUGENE KOVÁCS. Ger. 605,466, Nov. 10, 1934. Presses, rollers, molds, etc., for working fused glass and like melts are made from alloys containing Al 5.5 to 13 and Fe 4.5 to 8%, the remainder being Cu. The working temperature can then be raised to considerably above 620° without difficulties arising from the adhesion of the melt to the apparatus. (*C.A.*)

Apparatus and method for making glass. W. A. MORTON (Amco, Inc.). U. S. 1,994,959, March 19, 1935 (Feb. 13, 1929).

Blowing tubes open at both ends. A.-G. FÜR GLASINDUSTRIE VORM. F. SIEMENS. Ger. 605,647, Oct. 25, 1934 (Nov. 29, 1932). The parison is first blown out as a tube with a pronounced bulbous enlargement at the bottom so that the walls there are very thin, and this is then cut off by means of a plunger driven up from the base of the mold. (*J.S.G.T.*)

Bulbs containing alkali metal vapors. COMPAGNIE DES LAMPES. Fr. 765,474, June 11, 1934. A glass which is resistant to alkali metal vapors and of lower melting point than the glass of the bulb is powdered and fused onto the bulb or fritted *in situ*. The bulb may be of silicic glass and covered with a phosphate glass. (*C.A.*)

Clamp for glass. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,996,385, April 2, 1935 (March 15, 1932).

Cut-off burner for hollow glass articles. AUGUST KADOW (Libbey Glass Mfg. Co.). U. S. 1,996,814, April 9, 1935 (March 6, 1933).

Delivering mold charges. DEUTSCHER VERBAND DER FLASCHENFABRIKEN G.M.B.H. Ger. 605,462, Oct. 25, 1934 (April 15, 1920). The form and size of the gob dis-

charged from a feeder outlet are controlled by the level of the glass in the channel above the outlet. (*J.S.G.T.*)

Displacement glass feeder. PETER KUCERA (Hartford-Empire Co.). U. S. 1,997,799, April 16, 1935 (March 1, 1932).

Edge-grinding apparatus. R. J. LOUVIAUX (Libbey-Owens-Ford Glass Co.). U. S. 1,997,386, April 9, 1935 (Oct. 30, 1931).

Electric furnace for fusing and treating glass. PAUL RICHALET. Fr. 775,150, Dec. 20, 1934. (*C.A.*)

Furnaces for reheating glass. PILKINGTON BROS., LTD. Fr. 765,257, June 5, 1934. (*C.A.*)

Glass. BAKER & CO., INC. Fr. 766,834, July 4, 1934. The refractory surfaces with which the molten glass comes in contact on its exit from the furnace are covered with a layer of an alloy containing Pt and Rh, *e.g.*, 90 and 10%. (*C.A.*)

Glass. I. G. FARBENIND. A.-G. Fr. 43,500, June 7, 1934. Addition to Fr. 724,367 (*Ceram. Abs.*, **12** [3] 104 (1933)); see also Ger. 589,035 (*ibid.*, **13** [8] 207 (1934)). (*C.A.*)

Glassblowing machine. L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 1,998,336, April 16, 1935 (Nov. 1, 1930).

Glass-cutting apparatus. WILLIAM OWEN (Pittsburgh Plate Glass Co). U. S. 1,996,386, April 2, 1935 (Aug. 26, 1933).

Glass-cutting table. E. C. MILES (Pittsburgh Plate Glass Co.). U. S. 1,996,383, April 2, 1935 (July 7, 1934).

Glass feeder. S. B. BOWMAN. U. S. 1,997,510, April 9, 1935 (July 27, 1932). PETER KUCERA (Hartford-Empire Co.). U. S. 1,997,798, April 16, 1935 (Nov. 19, 1931).

Glass-forming machine. A. F. MCNISH. Brit. 426,275, April 10, 1935 (Jan. 31, 1934).

Glass machine alloy. A. W. GREGG AND R. H. FRANK (Bonney-Floyd Co.). U. S. 1,996,152, April 2, 1935 (April 24, 1933).

Glassware forming machine. C. W. SCHREIBER AND J. E. MCLAUGHLIN (Owens-Illinois Glass Co.). U. S. 1,995,628, March 26, 1935 (May 21, 1932).

Glassware leer construction. H. B. EASTWOOD (Hartford-Empire Co.). U. S. 1,997,250, April 9, 1935 (Dec. 2, 1933).

Glassworking apparatus and method. G. E. HOWARD (Hartford-Empire Co.). U. S. 1,995,276, March 19, 1935 (Oct. 21, 1931).

Hand apparatus for forming glass bottles from glass cylinders. GLASFABRIK WILHELMSHÜTTE, G.M.B.H. Ger. 594,205, Oct. 28, 1931; *Keram. Rund.*, **42** [49] 613 (1934).—The apparatus consists of a shell-like form made from tongs. The base is a hollow glass (cylinder) body supporting the bottle body in a suitably attached form and partially surrounding the bottle shoe and in combination with one of the tubes. A.K.

Heat-absorbing glass. JENAER GLASWERK SCHOTT & GEN. Ger. 604,146, Sept. 27, 1934 (Nov. 13, 1930). A glass absorbing heat and containing at least 0.2% iron as FeO has SiO_2 displaced wholly or partially by P_2O_5 or B_2O_3 to the extent of at least 25% of either. (*J.S.G.T.*)

Knife for suction-filled molds. EUROPÄISCHER VERBAND DER FLASCHENFABRIKEN G.M.B.H. Ger. 607,089, Nov. 29, 1934 (Feb. 4, 1933). The blade of the knife is set with a top rake sufficient to hold the following part of the knife, which makes the seal of the mold orifice, away from the latter until the blade has passed across. (*J.S.G.T.*)

Leer. W. O. FLEMING (Corning Glass Works), U. S. 1,995,974, March 26, 1935 (Nov. 22, 1933). CORNING GLASS WORKS. Brit. 426,042, April 10, 1935 (Nov. 22, 1933).

Leer-feeding apparatus. N. R. BECK (Carr-Lowrey Glass Co.). U. S. 1,996,535, April 2, 1935 (April 17, 1933).

Lens surfacing machine. L. L. GAGNON AND R. D. WHEELER (American Optical Co.). U. S. 1,995,676, March 26, 1935 (July 15, 1932).

Making glass tubing with longitudinal dividing wall. N. V. PHILIPS' GLOEILAMPENFABRIEKEN. Ger. 604,720, Oct. 11, 1934 (Jan. 3, 1933). The draw is made from a parison prepared by inserting a second gathering inside the usual hollow parison and uniting it with the walls of the latter, *e.g.*, by pressing them inward slightly to form the dividing wall. (*J.S.G.T.*)

Manufacture of glassware. J. E. DUNCAN, JR., AND W. W. REESE (Duncan & Miller Glass Co.). U. S. 1,996,910, April 9, 1935 (March 24, 1933).

Manufacture and production of glass which is permeable to ultra-violet light and stable to irradiation. J. Y. JOHNSON (I. G. Farbenindustrie, A.-G.). Brit. 424,366, March 6, 1935 (Dec. 2, 1933).

Method and apparatus for producing lens grinding laps. L. L. HOUCHIN (Robinson Houchin Optical Co.). U. S. 1,998,395, April 16, 1935 (April 21, 1933).

Method of fining glass and batch therefor. W. C. TAYLOR (Corning Glass Works). U. S. 1,995,952, March 26, 1935 (Aug. 3, 1933). The method of fining glass includes adding to the batch not over 2% of sulfur and salt cake and melting the batch.

Method of making multifocal lens segments. N. M. STANLEY (Univis Corp.). U. S. 1,996,442, April 2, 1935 (April 24, 1933).

Method of making partitioned glass containers. C. G. HILGENBERG AND C. B. GARWOOD. Brit. 424,393, March 6, 1935 (June 25, 1934).

Molds for use on glass-forming machines. F. A. HARRISON AND UNITED GLASS BOTTLE MANUFACTURERS, LTD. Brit. 426,311, April 10, 1935 (Nov. 2, 1934).

Ophthalmic lens and process of making. M. A. LAABS (American Optical Co.). U. S. 1,995,680, March 26, 1935 (Oct. 2, 1933).

Preparation of pure silica. PATENT-TREUHAND-GES. FÜR ELEKTRISCHE GLÜHLAMPEN M.B.H. Ger. 604,721, Oct. 11, 1934 (Feb. 27, 1933). A device for reducing precipitated silica to fine particles is incorporated into the precipitation vessel, so that reduction takes place immediately after precipitation. (*J.S.G.T.*)

Pressing glass. PILKINGTON BROS., LTD. Ger. 605,090, Oct. 18, 1934 (May 15, 1933). Immediately after the pressing operation is completed the plunger is lifted a short distance above the glass in the mold and held there until the glass is set, being then drawn back to its starting position. (*J.S.G.T.*)

Preventing tarnishing of sheet glass. MÜHLIG UNION GLASINDUSTRIE A.-G. Ger. 605,436, Oct. 25, 1934 (April 8, 1932). The sheets are packed with interlayers of mate-

rial treated with reagents that combine with alkali at ordinary temperatures. (*J.S.G.T.*)

Process and apparatus for annealing glass plates. PILKINGTON BROS., LTD., AND F. E. SLOCOMBE. Brit. 425,996, April 10, 1935 (Sept. 26, 1933).

Process for surfacing plate glass. W. G. ELY, JR. (Pittsburgh Plate Glass Co.). U. S. 1,996,369, April 2, 1935 (Aug. 16, 1934).

Production of colored effects during fashioning of glassware. T. P. KÖNIG AND F. PRACHT. Ger. 602,274, Aug. 23, 1934 (Feb. 4, 1932). Gold compounds dissolved or suspended in mixtures containing, *e.g.*, oils, fats, waxes, resins, tallow, or lacquers, are used to give a surface coloration on a hot parison which is then covered with another gather of glass. The color is applied by spraying or immersion in the liquid preparation. (*J.S.G.T.*)

Refractory glasses. GENERAL ELECTRIC CO., LTD., G. F. ADAMS, R. W. DOUGLAS, AND J. H. PARTRIDGE. Brit. 426,129, April 10, 1935 (Aug. 28, 1933).

Relieving rolls to prevent breakage in drawing sheet glass. VEREINIGTE VOPELIUS'SCHE & WENTZEL'SCHE GLASHÜTTEN G.M.B.H. Ger. 600,366, June 28, 1934 (April 24, 1933). In a process of drawing sheet glass in which the glass passes between a series of rollers journalled in fixed supports and a series so journalled that they swing away from the fixed series to permit irregularities in the sheet to pass, means are provided for carrying out the swinging apart operation mechanically. (*J.S.G.T.*)

Rotary vessel for withdrawing molten glass from a furnace. SOC. ANON. D'ÉTUDES ET DE CONSTRUCTIONS D'APPAREILS MÉCANIQUES POUR LA VERRERIE. Ger. 605,089, Nov. 3, 1934. This corresponds to Brit. 392,832 and 394,282 (*Ceram. Abs.*, **12** [9] 328 (1933)). (*C.A.*)

Safety device for glassware forming machines. G. E. ROWE (Hartford-Empire Co.). U. S. 1,995,653, March 26, 1935 (Aug. 22, 1933).

Shaping glass articles. CORNING GLASS WORKS. Brit. 424,929, March 13, 1935 (June 2, 1933).

Sheet-glass apparatus. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,996,387, April 2, 1935 (June 28, 1934). WILLIAM WILDERMUTH (Libbey-Owens-Ford Glass Co.). U. S. 1,996,448, April 2, 1935 (Aug. 10, 1933).

Sheet-glass cutting apparatus. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 1,997,402, April 9, 1935 (Jan. 29, 1927).

Sheet-glass inspection apparatus. E. L. WALTERS. (Libbey-Owens-Ford Glass Co.). U. S. 1,996,446, April 2, 1935 (June 18, 1934).

Vitreous products. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE SAINT-GOBAIN, CHAUNY, ET CIREY. Fr. 43,360, May 11, 1934. Addition to 746,004 (*Ceram. Abs.*, **13** [2] 38 (1934)). A modified form of apparatus is described. (*C.A.*)

Wine glasses, etc. STUART & SONS, LTD., AND F. C. PAULI. Brit. 424,509, March 6, 1935 (Oct. 14, 1933).

Structural Clay Products

Bond between reinforcing steel and brick masonry. E. F. GALLAGHER. *Brick Clay Rec.*, **86** [3] 92–93 (1935).—Special brick of four cross-sections were made up for tests to determine how it would be possible to increase the amount of mortar around reinforcing steel without materially increasing the amount of mortar required for the joints. The variables of the tests, other than the shapes of the brick, were in (1) thickness of joints, (2) size of the steel, and (3) type of mortar. The results are compared with similar tests made on assemblages in which the standard brick was used. Illustrated. E.J.V.

Materials in hollow-tile manufacture. W. DAWIHL. *Ziegelwelt*, **65**, 131–33 (1934).—The discussion deals with the effects of gradation and kind of raw materials and admixtures on the porosity and thermal properties of the finished clay building tile. (*C.A.*)

Moisture content of ware set in the kilns. JOSEF MATĚJKA. *Stavivo*, p. 450 (1933).—Brick set moist have lower strength after firing. A moisture content of 4% may reduce the crushing strength by almost 50%. Moisture content is the cause of higher percentages of kiln losses, retards the progress of the fire, favors the formation of scum, and has an unfavorable effect on fuel consumption. R.B.

Porous bodies and their behavior as building materials. B. H. WILSDON. *Brit. Clayworker*, **43** [515] 348–52 (1935).—The behavior of porous building materials is discussed in terms of capillary theory. The simple application of the Kelvin equation is inadequate to explain the properties of water in a finely porous material. The mechanical effects produced by water in porous bodies are discussed. The available work due to moisture absorption measured experimentally may be small compared with that estimated from the unrestrained moisture expansion and modulus of elasticity. It is suggested that the liability to mechanical damage through frost action or the crystallization of salts is determined largely by the effects of micropores in causing delayed transformations. R.A.H.

Progress in brickmaking. Great Britain's position. ARTHUR E. BROWN. *Brit. Clayworker*, **43** [514] 312–13 (1935).—The Hoffmann continuous kiln announced in Germany in 1858 and the mechanization of brickmaking by British engineers contemporary with that invention were the only steps of real progress in brick manufacture up to the time of the war. B. discusses the difficulties the manufacturer has encountered and points out the progress which has been made since that time in both building and fire brick. R.A.H.

Vitrified brick curb. G. F. SCHLESINGER. *Can. Engr.*, **68** [13] 14 (1935).—Owing to spalling and fracture of flush curb or headers of concrete, a change to a concrete base with integral brick curbs was made on the Portsmouth-Gallipolis road. The cost of installation of the brick curb is lower and, due to the toughness, durability, and lower coefficient of linear expansion of the vitrified brick, the stresses caused by expansion are expected to be reduced and the damage minimized. Construction details are given. Illustrated. E.J.V.

PATENTS

Brick embossing device. R. A. CLEM (Joseph Entwistle). U. S. 1,997,859, April 16, 1935 (Oct. 16, 1933).

Conduit. J. A. MILLSOM (W. S. Dickey Clay Mfg. Co.). U. S. 1,995,716, March 26, 1935 (July 15, 1933).

Lightweight clay product and process of making. CHARLES WEIGEL. U. S. 1,997,282, April 9, 1935 (Oct. 22, 1930). The brick has a lightweight fired clay body originally comprised of clay of high silica and low alumina content, lignite high in alkaline content, and bentonite up to 10% by weight of the clay, the body having large interconnected cavities distributed throughout, the walls of the cavities being covered by a coating of fused silica and an alkali.

Method of manufacturing brick. HENRIK NIELSEN. U. S. 1,995,576, March 26, 1935 (Oct. 24, 1930). The method comprises drying clay until the content of moisture is between 5 and 10%, granulating the dried clay, molding the granulated mass under pressure into blocks and firing the molded blocks.

Refractories

Aluminum and bauxite. C. L. MANTELL. *Mineral Ind.*, **42**, 13–31 (1933).—World production of Al again declined, totalling 134,000 metric tons. Trade, new uses of Al, and production of bauxite are also discussed. (*C.A.*)

Ceramic materials for investigation of technologically important fusion electrolyses. H. BORCHERS. *Metallwirtschaft*, **14** [8] 149–51 (1935).—The difficulties of obtaining materials which will stand the high temperatures of molten salt baths for electrolytic purposes are pointed out, and some new materials now made of oxides which are fired at very high temperatures are described. Crucibles and tanks are made of corundum of purest alumina, of beryllium oxide, or other oxides fired at high temperatures. They will stand molten sodium fluoride, cryolite, and magnesium salts at temperatures as high as 1345°C (2450°F) without destruction. M.H.

Chrome refractories. W. E. PATTERSON AND C. C. WEEKS. *Can. Chem. Met.*, **19** [3] 60 (1935).—Experiments in lining a furnace with a plastic chrome mix, where Cape Breton coal had been producing a viscous slag that eroded the refractory brick, showed that chrome refractories have a marked usefulness in settings where the coal burned has a low fusing ash. E.J.V.

Conversion of quartz into cristobalite below 1000°C, and properties of the cristobalite formed. SANDFORD S. COLE. *Jour. Amer. Ceram. Soc.*, **18** [5] 149–54 (1935).—Bibliography.

Defects in refractory ware. R. BARTA. *Zpravy Ceskoslov. keram. spolecnosti*, **10** [1–2] 80–83 (1933); abstracted in *Tonind.-Ztg.*, **58** [43] 522 (1934); *Sprechsaal*, **67** [30] 450 (1934).—Defects due to structure, chemical and mechanical composition, unsuitable use, etc., are discussed. M.V.C.

Evolution of coke-oven refractories. W. J. REES. *Refrac. Jour.*, **11** [2] 55 (1935).—Silica brick have been established as the best coke-oven refractory due to (*a*) high durability and flexibility, (*b*) high thermal efficiency, and (*c*) high resistance to corrosion from salty coals. The I.G.E. specifications for coke-oven silica brick are given and include those of (1) shape, finish, and dimensions, (2) chemical composition, (3) refractoriness, (4) efficiency of firing and degree of quartz conversion, (5) volume stability at high temperatures, (6) mechanical strength at high temperatures (refractoriness under load), and (7) porosity and cold crushing strength. M.C.S.

Fire brick (silica brick). E. ROSTRUP. *Gjuteriet.*, No. 2, p. 22 (1933).—The coloring method is used to determine stability. Methyl blue is absorbed in all the fine cracks in the destroyed quartz particles. Ferriferrous spots turn brown. Different samples were examined for resistance to molten slag. (*C.A.*)

Fireclay refractories for glassworks use. ANON. *Glass*, **12** [2] 52 (1935).—The equilibrium diagram of the alumina-silica system is taken up and many of its more important phases are discussed. The effects of iron oxide, titania, lime, magnesia, manganese, fluorine, carbon, sulfur, and the alkalis upon clays used for glasshouse refractories are briefly discussed. M.C.S.

High-temperature insulation for industrial furnaces. IV. N. ALLEN HUMPHREY. *Blast Fur. Steel Plant*, **23** [3] 198–99 (1935).—In determining the most economical thickness of insulation, H. shows that a diminishing saving is made by the use of successive unit thicknesses of insulation applied against the source of heat. The cost of available heat in the furnaces, hours of operation, cost of insulation, and return on the investment for the outer inch of insulation determine the economical thickness for a furnace. Examples of calculations on furnaces are given. For Part III see *Ceram. Abs.*, **14** [5] 117 (1935). E.J.V.

Hydraulic set refractory bodies. W. GRAF CZERNIN. *Ber. deut. keram. Ges.*, **15** [9] 463–71 (1934).—This discussion of hydraulic refractory cements shows the close connections possible between the cement and refractory industries. Plastic refractories are used for patching and for protecting joints between refractories. A comparison of compositions of Portland and alumina cements is made, and the possibility of predicting softening points of alumina cements from the binary system lime–alumina is pointed out. Kestner cement, Firecrete, an improved product, and a plastic refractory composed of grog and a clay bond are discussed as to composition, behavior, strength, and shrinkage at various temperatures. E.J.V.

Incongruent fusion of mullite and its significance in industrial practice. V. ŠKOLA. *Zpravy Ceskoslov. keram. spolecnosti*, **10** [1–2] 64–67 (1933); abstracted in *Tonind.-Ztg.*, **58** [43] 522 (1934); *Sprechsaal*, **67** [30] 449 (1934).—Careful study of substances containing mullite or sillimanite showed that decomposition of mullite begins under certain conditions at temperatures lower than 1830°. If mullite is heated a long time at 1550°, corundum is formed together with a liquid phase which separates from the corundum. The possible importance of this in industrial practice is pointed out. M.V.C.

Increasing the chemical resistance of refractories for glass tanks. P. P. BUDNIKOFF. *Ber. deut. keram. Ges.*, **15** [10] 505–13 (1934).—As a result of experiments to increase chemical resistance of glass-tank refractories, B. found that (1) iron-containing additions introduced into the refractory batch aid in the conversion of the kaolinite

into mullite; (2) the mullite conversion of kaolinite corresponds to the practical requirements only if the iron-containing addition is present in a very finely dispersed state and uniformly divided; (3) refractories highly converted to mullite have a greater resistance to molten glass; (4) ochery clay with a high iron content in the form of hydroxide forms a suitable addition for mullite formation; (5) to obtain a complete conversion to mullite the brick must be fired to Seger cones 12 to 13 (about 1350 to 1380°C); (6) refractories for glass tanks have a high resistance to attack by green bottle glass; (7) as the formation produces a crystal formation which protects the brick against glass attack, the presence of the increased content of iron oxide has no effect on the color of clear glass; (8) undoubtedly the porosity and uniform pore distribution have a great effect on the resistance of refractories to glass attack. The porosity of the brick must be such as to make it resistant to temperature changes. E.J.V.

Increasing slag resistance of refractories. D. P. Bogatzkiĭ. *Metallurg*, **9** [3] 42–48 (1934).—A study of refractories consisting principally of alumina, silica, magnesia, or zirconia and methods of preparation which will increase their resistance to slagging is given. (*C.A.*)

Lightweight cellular brick made for furnace insulation. T. E. Wood. *Iron Age*, **135** [6] 26–28 (1935).—Details are given of the manufacture, use, and types of insulating brick and refractory shapes of low thermal conductivity and light weight made by the Armstrong Cork and Insulation Co. The brick and refractory shapes are made of pulverized diatomaceous earth mixed with ground cork and clay. A.K.

Permeability of some refractory bodies to hydrogen. W. Baukloh and A. Hoffmann. *Ber. deut. keram. Ges.*, **15** [8] 424–33 (1934).—A series of tests on permeability of some refractory materials to gases at elevated temperatures was conducted. Most materials have little permeability, as can be clearly determined. It is difficult to give a theoretical explanation for this phenomenon as in most of the bodies the chemical and physical conditions have not been strictly determined. Sinkterkorund is an exception as it shows a lower permeability at high temperatures than at low temperatures. This must not, however, be taken as a final result for Sinterkorund. The method of manufacture influences the permeability behavior of refractory materials. E.J.V.

Production of compact grog mixtures by mixing fractions of different grain sizes. János Pikler. *Magyar Mérnök Épitészegylet Közlönye*, **66**, 213–17 (1934).—Maximum compactness is obtained if the liter-weight curve of the finer fraction begins at the fracture points of the liter-weight curve of the previous fraction or at that of the curve of free area. The grain-size composition of the mixture having maximum liter weight can not be determined by calculation. (*C.A.*)

Properties of glasshouse refractories. J. W. Wright. Presented at Conference on Glass Problems, Urbana, Ill., June, 1934; abstracted in *Ceram. Ind.*, **22** [7] 380 (1934). E.J.V.

Quick determination of porosity of grog articles. V. Streletz. *Ogneuporui*, **2** [9] 43–45 (1934).—The proposed method consists in absorption of water under vacuum. S. states that reliable results can be obtained in 50 min. instead of several hours. P.B.&E.S.

Recent improvements in physical properties of silica brick. Sandford S. Cole. *Blast Fur. Steel Plant*, **23** [3] 221 (1935).—In considering methods of improving silica brick, source and type of raw materials, composition of finished product, and service requirements must be considered. The effect of Na_2O, CaO, FeO, and Al_2O_3 on the melting behavior of SiO_2 is discussed, showing why silica brick in open-hearth crowns are unaffected by material increase in lime and iron oxide content from the furnace charge. In silica brick manufacture workmanship has improved. E.J.V.

Refractories for high-temperature furnaces. F. E. Lathe. *Can. Engr.*, **68** [11] 27 (1935).—Future refractories will be developed (1) to withstand higher temperatures, (2) to be used unfired in brick form, and (3) for special purposes. An effective dolomite brick is needed. The history and applications of refractories are outlined. E.J.V.

Refractories: their manufacture and application. Edgar H. Pratt. *Nat. Engr.*, **38**, 298–300 (1934).—Some of the basic principles involved are reviewed. (*C.A.*)

Refractory stone of the silicic acid-alumina system. Heinrich Herbst. *Feuerungstechnik*, **23** [1] 1–3 (1935).—To produce refractory stone from any material containing silicic acid and alumina according to the silica-alumina system, it is necessary to determine what per cent of free silica the raw material yields above the "mullite" composition during firing at high temperatures, in order that this free silica will be combined into high-melting compounds in a way similar to that described in the examples. M.V.C.

Silica and the coke oven. Harold Shaw. *Refrac. Jour.*, **11** [3] 111 (1935).—S. discusses the care which must be exercised when starting fires in a newly constructed coke oven. Unless a carefully planned heating schedule is followed it is entirely possible to ruin the efforts and exacting work of both the silica brick manufacturer and the contractor or builder. M.C.S.

Steel: barometer of industry. Russell Owen. *New York Times Mag.*, March 10, 1935.—The operation of a steel mill with special mention of the refractory-lined furnaces is described. M.V.C.

Trends of research in refractories used in steel plants. J. H. Chesters. *Brick Clay Rec.*, **86** [3] 96–97 (1935).—Research work on refractories for steel plants and its effect on future fireclay, silica, magnesite, chromite, and special refractories are discussed. Electrocast chrome spinel and mullite blocks have been introduced and the process may be extended to the production of special steel refractories. Illustrated. E.J.V.

Variations in pyrometric cone equivalent of refractories after reheating at elevated temperatures. D. A. Dickens, S. S. Cole, and M. E. Holmes. *Bull. Amer. Ceram. Soc.*, **14** [4] 135–38 (1935).

BOOKS

Magnesia refractory materials. P. P. Budnikoff. *Reference Leaflets of Central Council of All-Union Inventors' Soc.*, Vol. 12, Nos. 224–28 (1933—issued 1934).—The uses of magnesia refractories are described. Chemical

and physical characteristics of magnesite deposits in the U.S.S.R., the U.S.A., and other countries are given. Methods of production are described, with a special reference to the Satka plant in the Ural. B. discusses the mining of magnesite rock, firing of magnesite, preparation of the mass, molding, drying, and firing of the brick. The properties of magnesite brick and claims made for it are given. Magnesia materials produced without subsequent firing and magnesite nozzles for casting steel are described. Bibliography. P.B.&E.S.

Manufacture of bottom stones. M. A. MAKAROV. Edited by E. I. Derechey. State Sci. Tech. Pub. House of "Black" (Ferrous) and "Color" (Nonferrous) Metallurgy, Moscow, Leningrad, and Sverdlovsk, 1934. 16 pp. Price 30 kopeks. This small practical brochure deals with the manufacture of bottom stones for electric furnaces of the Ajax-Wyatt system used for brass melting. The following types of stones were manufactured: (1) grog (83 to 86% grog and 17 to 14% refractory clay, fineness of grind from 0.1 to 4.5 mm.; these stones served from 4 to 600 heats); (2) corundum (chemical composition of corundum: alumina 89.92, silica 3.06, ferric oxide 2.66, calcium oxide 1.5, magnesia 0.18, titanium dioxide 0.57, ignition loss 1.62%, binding clay from 16 to 20%; served from 450 to 2300 heats but absorbed liquid metal); (3) quartz (quartz of 2 to 5 mm. grain size with 25% of clay and water-glass 12° Bé is used for molding the stones which were put into the furnace unfired (only dried); served 2000 to 2300 heats). Quartz stone manufacture is outlined in detailed. S. I. PERKAL

PATENTS

Appliance for remedying the edge cutting of interlocking tile by saggers. RICHARD RAUPACH MASCHINENFABRIK. Ger. 593,553, Aug. 9, 1932; *Keram. Rund.*, **42** [49] 613 (1934).—The inner surface of the saggers consists of a coating of a plaster body made of elastic tongues which extend the whole length or are just on the angular points of the walls of the saggers. A.K.

Furnace materials. MEYERHOFER & Co. Fr. 775,024, Dec. 18, 1934. Refractory brick which are subjected to the action of corrosive substances are made of materials which become porous on firing, the porosity being as high as is consistent with sufficient mechanical resistance. The mortar is also porous. (*C.A.*)

Glass tank furnace and block therefor. P. G. WILLETTS (Hartford-Empire Co.). U. S. 1,996,266, April 2, 1935 (Dec. 15, 1928).

Making alumina crucibles without bond. SIEMENS & HALSKE A.-G. Ger. 605,629, Oct. 25, 1934 (May 7, 1931). Crucibles for use in melting ultra-violet transmitting glass are prepared from pure iron-free alumina previously sintered at a temperature of at least 1700°. The material is purified by chemical means and is used to coat the surface of the crucible in contact with the glass. (*J.S.G.T.*)

Manufacture of refractory magnesia products. C. ARNOLD (Non-Metallic Minerals, Inc.). Brit. 424,741, March 13, 1935 (April 27, 1934).

Methods and means for preparing refractories and refractory masses so produced. R. BOSCH A.-G. Brit. 425,702, April 3, 1935 (Nov. 10, 1932).

Porous articles. SIEMENS & HALSKE A.-G. Fr. 757,-864, Jan. 5, 1934. Oxides of Al, Be, Cr, Mn, Zr, Mg, or Hf are fused, ground, and screened to a determined size, made into a paste by the addition of a mud made with the same or similar material, and activated by a dilute acid until a friable mass is obtained. The articles are formed by pressing and agglutinated at a temperature above 1600°. (*C.A.*)

Porous articles. SIEMENS & HALSKE A.-G. Fr. 757,-995, Jan. 8, 1934. A diluted acid is added to the finely ground material and a concentrated acid to the larger-grained material so that a uniform extraction of moisture with a minimum period of absorption in the molds is obtained. (*C.A.*)

Process for preparing brick and molded articles from high refractory metallic oxides. FELDMÜHLE, PAPIER- UND ZELLSTOFFWERKE A.-G., FRIEDRICH KLEIN, AND KARL BECHTEL. Ger. 594,297, March 20, 1933; *Keram. Rund.*, **42** [49] 613 (1934).—Brick stable to temperature change and corrosion-proof are made of aluminium oxide, magnesium oxide, or mixtures thereof by fusing and pouring into a metal mold. The wall strength of the formed shape is so low in proportion to the volume and the area that the solidification of the interior takes place progressively from the outside edge inward due to the low heat capacities of the shapes. The porosity and crystal structure of the molded ware shows a limit where cracking occurs parallel to the surface. A.K.

Preservation of metallurgical furnace bottoms. A. T. CAPE AND K. B. BOWMAN (Republic Steel Corp.). U. S. 19,517, April 9, 1935 (Oct. 25, 1933), reissue. The method of preserving metallurgical furnace bottoms which are normally subject to disintegration by the expansion of slag, which seeps therein and expands on solidification and subsequent cooling, consists in incorporating a borate with the slag before the latter solidifies.

Production of colloidal aluminum hydroxide and the colloidal aluminum hydroxide produced. P. S. MOYER. Brit. 424,734, March 13, 1935 (March 23, 1933).

Protector for hot top rings. W. M. CHARMAN. U. S. 1,997,677, April 16, 1935 (Jan. 18, 1934).

Refractory compositions. SIEMENS & HALSKE A.-G. Brit. 410,988, May 31, 1934.

Refractory lining for furnaces. QUIGLEY CO., INC. Fr. 766,377, June 27, 1934. The lining is made in a single piece of a relatively pure spinel, *e.g.*, a relatively pure picotite produced by synthesis. An example is made from calcined magnesite 3, chromite 3, and a rapid-setting cement (containing Al 54, CaO 38, and SiO_2 8%) 1 part. (*C.A.*)

Refractory materials. FERRO ENGINEERING CO. Fr. 766,017, June 7, 1934. A refractory material contains approximately dry Na_2SiO_3 or its equivalent 4.7, oxide of Pb, Zn, or Al 1, and sand 94%. (*C.A.*)

Refractory materials. VICTOR M. GOLDSCHMIDT (Rolf Knudsen, co-inventor). Ger. 605,371, Nov. 9, 1934. Ferruginous minerals rich in Mg orthosilicate, *e.g.*, olivine, peridotite, or dunite, are comminuted and mixed with material rich in Mg, *e.g.*, MgO, with or without clay or an organic binder. The mixture, which may be molded if desired, is then heated to a high temperature below its melting point. (*C.A.*)

Terra Cotta

Bentonite as a means of increasing the cristobalite content and resistance to crazing of glazed ceramic ware. H. G. SCHURECHT. *Ceram. Ind.*, **24** [4] 219 (1935).—Cristobalite in ceramic bodies causes them to contract more than the glaze during cooling in kilns below 240°C, places the glaze in compression, and makes the bodies resistant to crazing. Fired bentonite would contain about 53.2% cristobalite and thus the cristobalite content of a body may be increased by adding bentonite to the mix. E.J.V.

Dry or wet method of producing tile. GURVITSCH, CHAVKIN, LAPOVOK, AND PETSHURO. *Stroitel. Material.*, No. 8, pp. 25–35 (1934). P.B.&E.S.

Operating defects in stoneware manufacture, its preparation, and knowledge obtained through expansion measurements according to Steger. OTTO LIEBELT. *Ber. deut. keram. Ges.*, **15** [8] 416–24 (1934).—Data on tests made to determine causes of failure in stoneware production are presented. These tests included a series of varied duration of grinding of the body mix, a uniform biscuit fire, the same glaze with a uniform glost fire and variations in the firing treatment; thermal expansion measurements were then made on the test pieces. E.J.V.

Sanitation and clayware. W. H. KNIGHT. *Brit. Clayworker*, **43** [514] 319–22 (1935).—House drains, tiled lavatories, etc., were used in Mesopotamia probably 5000 years ago. Ravages of diseases in modern times brought about the passage of numerous public health acts. K. deals with the clayware industry and its connection with the science of sanitation. Ceramic art is one of the most ancient in existence. Modern knowledge and efficiency have rendered possible the successful production of sanitary ware of three types, *viz.*, earthenware, fireclay ware, and vitreous china. R.A.H.

Standard specifications for stoneware for sewage disposal. ANON. *Keram. Rund.*, **42** [32] 399–400; [39] 487–89; [40] 501–503 (1934); *Tonind.-Ztg.*, **58** [65] 781–82; [66] 793–95 (1934). M.V.C.

Tile. H. R. COLE. *Keram. Tile Jour.*, **7** [2] 11 (1935).—C. gives a historic sketch of the evolution of the use of ceramic tile from many thousand years B.C., when tile were found to be used in the ancient temples of China, through 1878 when the first tile plant was founded in this country, up to the present day. Not only are ceramic tile an inexpensive construction material but they also add beauty and present a surface which can easily be kept clean and sanitary. M.C.S.

PATENTS

Process for coating surfaces of slate, concrete, or brickwork. COLLOID COLOURS, LTD., AND R. G. DURRANT. Brit. 424,919, March 13, 1935 (Jan. 30, 1934).

Tiled floor. S. W. CHAFFEE. U. S. 19,518, April 9, 1935 (April 17, 1933), reissue. A floor or wall construction comprises a relatively thin unyielding tile section, a body of substantial thickness of a plastic yielding but resilient material, and a sheet of flexible fabric, the parts of the construction being bonded together in such relation that the tile section is yieldingly supported by the body of plastic resilient material but is held in position with respect to the backing sheet independently of other parts of the construction whereby the construction without damage thereto is capable of distortion under substantial force applied thereto.

Whiteware

Determining origin of seeds in porcelain and faience ware. V. P. ZUBCHANINOV. *Keram. i Steklo*, **10** [6] 21–22 (1934).—The origin of seeds can be exactly determined by means of a mineralogical examination of particles larger than 0.01 mm. separated from the dried mix by means of soaking it in water and in a liquid with a high specific gravity. Details of the method are given. The examination of thin sections of the finished ware is without results. M.V.C.

Fine stoneware mixes for tableware. V. P. ZUBCHANINOV AND Z. I. GLUSHANOK. *Keram. i Steklo*, **11** [1] 27–30 (1935).—The composition and properties of stoneware mixes for tableware are analyzed. Results are tabulated. M.V.C.

Influence of humidity on flashover voltages of insulators. E. ALESSANDRI. *Ind. Vetro e Ceram.*, **7**, 374–87 (1934).—For porcelain and glass insulators, the flashover voltage is related to the humidity of the air by the equation $V = V_0 + k \cdot f$, where f is the humidity and k varies with the type of insulator. Plotting flashover voltage against absolute humidity thus gives a linear relation. Data are given for porcelain insulators, the equations being $V = V_0 + k \cdot f = [142.3 + 5.04f]$ kv. for a three-skirted type, 340 mm. high, 350 mm. maximum diameter; $V = (128.3 + 6.06f)$ kv. for a four-skirted white-glazed porcelain insulator 300 mm. high and 360 mm. maximum diameter, and $V = (211 + 0.78f)$ kv. for a four-skirted brown-glazed porcelain insulator, 380 mm. high and 400 mm. maximum diameter. For a chain of six insulators $V = 308 + 6.0f$ represents the relation between flashover voltage and absolute humidity. For relative humidities greater than 80% these linear equations no longer hold. Flashover voltages for an insulator can only be given for a definite barometric pressure, temperature, and humidity and should be referred to 760 mm. pressure, 20°, and a humidity of 11 mm., *i.e.*, relative humidity of 65% at 20°. (*J.S.G.T.*)

Microstructure of some porcelain glazes. I. S. KONDO AND T. L. TONG. *Jour. Jap. Ceram. Assn.*, **42**, 539 (1934).—A study was made of the microstructure of 51 porcelain glazes of the composition 0 to 1.0 $KNaO$, 1.0 to 0.0 CaO, 0.467 to 1.3 Al_2O_3, 2 to 12 SiO_2. The alumina was calculated from the Sortwell formula: $Al_2O_3 = 0.3 + SiO_2/12$ (equivalents). The glazes were applied thickly on small biscuit porcelain tile and fired to cone $17\frac{1}{2}$ in a coal-fired commercial kiln. The conclusions are as follows: (1) good mat glazes owe their matness to numerous minute crystals of anorthite or mullite; (2) in many semi-mat glazes the texture is spoiled by the undissolved

quartz, each grain of which is surrounded by a fringe of clear glass; (3) most of the good bright glazes contain undissolved quartz grains and many have crystals of anorthite or mullite; (4) leucite crystals were present only in a glaze fired to cone 8; (5) quartz grains with evident signs of inversion and showing devitrification rims were observed only in a glaze fired to cone 10. (*T.C.S.E.*)

Steatite-containing bodies in the ternary system MgO–Al_2O_3–SiO_2. Otto Krause and Ernst Jäkel. *Ber. deut. keram. Ges.*, **15** [9] 485–500 (1934).—A study of the sintering behavior, mechanical properties, and structure of 15 steatite-containing bodies in the ternary system MgO–Al_2O_3–SiO_2 was made. The reduction of the coefficient of thermal expansion can be traced to the formation of cordierite, but the relation between coefficient of thermal expansion and structure indicated by F. Singer does not hold. On account of the too brief sintering interval and the low mechanical stability the possibility of producing such bodies must be judged as remote. See also *Ceram. Abs.*, **14** [2] 56 (1935). E.J.V.

Tests on high-frequency line insulators. M. Boella. *Alta Frequenza* [Milan], **1**, 221–37 (June, 1932).—A resonance method of measurement, by comparison with high ohmic resistance, has permitted tests on capacity and dielectric losses of bell-shaped insulators suitable for high-frequency telephone lines. Measuring devices and results of the tests are described, which were made on a frequency range from 10^4 to 10^5 hertz in various atmospheric conditions: dry and damp air, fog, and rain. These trials have pointed out the lack of value of direct-current insulation tests and have suggested new ideas for the design of insulators. Metallizing the head of the insulator has reduced to one-half the conductance under rain, without an important increase of capacity. Using a guard ring connected to the line and placed about two centimeters under the insulator has allowed a further reduction of about 50% in losses. (*R.S.I.*)

Water softening for bodies and glazes. II. John H. Grady. *Ceram. Ind.*, **24** [4] 236–38 (1935).—Information on the character and quantity of minerals in water is obtained from the hardness, carbon dioxide, acidity, and alkalinity as determined by phenolphthalein and methyl orange. Methods for making these determinations are given. Determining the amount of coagulant by bottle tests is also explained. For Part I see *Ceram. Abs.*, **14** [5] 128 (1935). E.J.V.

PATENTS

Insulator. M. H. Hunt and G. M. Barrow (Westinghouse Electric & Mfg. Co.), U. S. 1,997,688, April 16, 1935 (Oct. 6, 1933). J. J. Taylor (Ohio Brass Co.), U. S. 1,997,439, April 9, 1935 (March 20, 1934). G. M. Whisler (Westinghouse Electric & Mfg. Co.), U. S. 1,997,666, April 16, 1935 (May 3, 1933).

Preparation of fused glass-ceramic joints. Porzellanfabrik Kahla. Brit. 424,442, March 6, 1935 (Nov. 23 1932).

Production of electrical insulating materials. Steatit-Magnesia A.-G. Brit. 424,601, March 6, 1935 (Feb. 21, 1933).

Production of glazed ceramic products of low coefficient of expansion. Porzellanfabrik Kahla. Brit. 425,737 April 3, 1935 (June 26, 1933).

Equipment and Apparatus

Apparatus for measuring the coefficient of thermal expansion. A. Heinz. *Stavivo*, p. 448 (1933).—H. describes the apparatus of Didier, Steger, Steinhof, and Nopitsch, the dilatometer of Chevenard, the Hirsch-Pulfrich cathetometer, and the dilatometer with photographic registration. See also "Electric—" *Ceram. Abs.*, **14** [5] 122 (1935). R.B.

Continuous process cuts clay-forming time from 3 days to 20 minutes. A C Spark Plug Co. *Ceram. Ind.*, **24** [4] 212–14 (1935).—A continuous system of four production lines fed by two continuous filters, each containing a de-airing pug mill and special drier, has resulted in a better product in less time, with less floor space, labor, and less waste material. Mechanical sentinels check differences of 2° in the temperature of the slip, a fraction of a point variation in the vacuum pressure on the de-airing machine, or a slight change in moisture content of the clay. Photoelectric cells actuate gate-type cutters, count blanks, etc. Illustrated. E.J.V.

Correcting faults in waste-heat driers. H. L. Longenecker. *Brick Clay Rec.*, **86** [3] 99–100 (1935).—The need for a booster furnace on waste-heat driers often results in aggravation of scumming and efflorescence and runs up fuel costs. Use of exhaust steam from the engines and live steam through the same coils will cut fuel costs and give good drying results. Close grouping of the kilns around or near the drier eliminates heat loss in the flues. Careful construction of the main distributing flue under the drier also aids in correcting improper or uneven drying. Setting of the ware to be dried affects drier efficiency. Illustrated. E.J.V.

Laws of material grinding. P. Rosin and E. Rammler. *Ber. deut. keram. Ges.*, **15** [8] 399–416 (1934).—The following law of grain composition for the weight characteristics of ground material was found to apply: $R = 100e^{-bx^n}$, where e is the base for natural logarithms, x the grain size in μ, R the residue in per cent, *i.e.*, the portion of the ground material whose grain size is greater than x, and b and n are constants. The rule is valid for a wide variety of materials, for those of crystalline nature, independent of crystal system, the hardness and the specific gravity (silica sand, feldspar, baryta, gypsum, magnesite, clay), as well as for amorphous materials (flint, glass). It is also applicable to the different cements and coal dusts. It is suitable only for the finest ground hematite and it is not satisfactory for brick. The e-law is practically a universal law. It is doubtless a simplification of a complicated conformity to law. It is not valid for coarse grinding in crushing mills but is valid for the fines from the centrifugal mill (under 1 mm.). The applicability of these laws to the grinding of materials with various kinds of mills is discussed. E.J.V.

Oven and drier construction. C. F. Mayer. *Ind. Heating*, **2** [3] 149–51 (1935).—M. describes a furnace with insulated steel panel walls consisting of steel plates between which a heat-insulating material with slots is placed

so that the path of the heat from the inside to the outside is considerably lengthened with resulting reduction of heat losses. M.H.

Petrographic microscope in ceramics. KÄSTNER. *Ber. deut. keram. Ges.*, **15** [8] 444–48 (1934).—Applications for a petrographic microscope, such as examining raw materials, checking the mineral composition and structure of ceramic products, etc., are cited. See also *Ceram. Abs.*, **14** [4] 100 (1935). E.J.V.

Power and heat economy in brick plants. A. BUCH. *Ber. deut. keram. Ges.*, **15** [9] 471–79 (1934).—Power requirements in an electrically operated brick plant are studied and possible economies in power consumption and drying are pointed out. A careful heat balance on firing operations is used to show avoidable heat losses. E.J.V.

Simultaneous drying and fine grinding of moist materials. ERNST ROTHELIUS. *Tek. Tid. Uppl. C, Kemi*, **64**, 57–64 (1934).—Various types of combination grinding mills and air-current sieves are discussed. The principles of the Raymond, Humboldt (Hochleistungs-Mahlgruppe), Pfeiffer, Loesche, Fuller, and Remo mill systems are described and illustrated, and diagrams showing the relationship between moisture, fineness of grinding, and efficiency are given. The drying and grinding of different coals are treated in detail. (*C.A.*)

Standard sieves. H. W. GARTRELL. *Chem. Eng. Mining Rev.*, **27**, 129–31 (Jan., 1935).—Tables show the differences between the new British, the Tyler, and the I.M.M. standard sieves in aperture, tolerance, etc. Illustrated. H.H.S.

Temperature and its measurement. E. O. MATTOCKS. *Ind. Gas*, **13** [1] 7–9; [2] 15–18 (1934).—The various types of gas-measuring instruments and their limitations are described. Conditions necessary for accurate measurement of gas temperatures with the American Gas Assn. high-velocity thermocouple are given. This thermocouple permits the precise measurement of temperatures in a furnace, the walls of which are either hotter or colder than the gas. The spectral line reversal method is also described. This has been used successfully to measure temperatures from about 1300° to well over 2000°. Brief reference is also made to the use of thermocouples for measuring surface temperatures and to the use of thermopiles for testing radiant heaters. (*C.A.*)

Thermal dehydration or decomposition of certain minerals or salts. A. F. GILL. *Can. Jour. Research*, **10** [6] 703–12 (1934).—A thermal decomposition apparatus long used in G.'s laboratory is described. It is an improved form of the combination of calcining furnace and weighing balance which allows continuous weight determinations to be made of samples undergoing thermal decomposition. The accuracy of the results is improved by suspending a thermocouple, supported by the balance, directly in the charge, the connecting leads being as fine as possible without adding significantly to the resistance of the pyrometer circuit. Thermal decomposition data are given for magnesite, hydromagnesite, magnesitic dolomite, dolomite, serpentine, asbestos, calcium and magnesium hydroxides, gypsum, hydrous magnesium sulfate, hydrous aluminum chloride, pyrite, and certain samples of coal of high "volatile" content. E.J.V.

Vacuum presses. K. DELIUS. *Ber. deut. keram. Ges.*, **15** [10] 503–505 (1934).—The results obtained by use of vacuum pressing in ceramics and future possibilities are discussed. E.J.V.

BULLETINS

De-airing stiff-mud bodies for clay products manufacture. J. O. EVERHART, C. R. AUSTIN, AND W. C. RUECKEL. *O. S. U. Eng. Expt. Sta. Bull.*, No. 74; reprinted in *Claycraft*, **8** [3] 120 (1934); **8** [5] 202; [6] 243 (1935). M.C.S.

Effect of soot on heat transmission in small boilers. P. NICHOLLS AND C. E. AUGUSTINE. *Bur. Mines Rept. of Invest.*, No. 3272, 14 pp. Free. The report gives results of a study of small boilers operating at low rates of firing to determine the reduction in efficiency resulting from the insulating effect of deposits of soot. Investigation shows that soot deposits decreased the heat absorbed by the boilers 2 to 7%, depending on the thickness of the deposits, instead of the large proportionate decrease (sometimes as high as 50%) suggested in statements previously issued. R.A.H.

PATENTS

Apparatus for projecting molten pulverized bodies. F. P. C. BENOIT. U. S. 1,998,217, April 16, 1935 (Feb. 25, 1933).

Clay-feeding device. WILLIAM MCCLINTOCK (Pacific Clay Products). U. S. 1,996,930, April 9, 1935 (April 5, 1933).

Device for stacking shaped objects, e.g., molded articles of the tile and brick, on a conveyance. HENRICK NIELSON. Ger. 594,073, Oct. 31, 1932; *Keram. Rund.*, **42** [49] 613 (1934).—At regular intervals between the stacked ware are slabs or forms. These are used for piling the ware in the desired spaced intervals. Fitted forms, in which the material is placed in stacking on the conveyance, are used by the different sized objects. A.K.

Drying device. A. TREPLIN AND CO. NACHF. KOMMGES. Ger. 594,155, Nov. 18, 1930; *Keram. Rund.*, **42** [49] 613 (1934).—Angular to the surfaces of the ware to be dried are arranged guide walls for conducting the hot streams of air for drying. The distance of the individual guide walls from each other is 20 mm. or less. A.K.

Knee-lever drive for presses. HUMBOLDT-DEUTZMOTOREN A.-G. Ger. 594,210, Dec. 14, 1927; *Keram. Rund.*, **42** [49] 613 (1934).—The abutment of the driving gear is circumjacent a small dimension which is straight and so far above or below the orbit of the center of the cross-head that the pressure of the knee lever on the cross-head guide is not changed. A.K.

Machines for producing brick, roofing tile, etc. W. S. POWEL. Brit. 425,248, March 20, 1935 (Nov. 14, 1933).

Tile cutter and breaker. S. I. GRANITE. U. S. 1,995,741, March 26, 1935 (July 27, 1931).

Turning device for drying rooms. BRAUNSCHWEIG MACHINE MFG. CO. Ger. 593,765, Dec. 13, 1932; *Keram. Rund.*, **42** [49] 613 (1934).—The time of drying of the ware is regulated in the drying rooms by a variation of radial slot openings or by an attached air-exhausting device in the closed front wall. The principle, similar to that of Venetian blinds, consists of overlapping rotary

dampers installed in such a way that the interior damper in the middle of the drying room opens more quickly and wider than the dampers further toward the exterior. The dampers in the turning space of the room or passage project inside to bring about an effective rotation of the material to be dried. A.K.

Kilns, Furnaces, Fuels, and Combustion

Calculating consumption of fuel by periodic furnaces. A. Bazilevich. *Keram. i Steklo*, **11** [1] 17–20 (1935).—A method of calculating shows the dependence between the consumption of fuel and the temperature and gaseous conditions of firing, type of furnace, kind of ware, and other related conditions. Formulas and diagrams illustrate the discussion. M.V.C.

Comparison of the temperatures in a solid and its scaled model. R. V. Churchill. *Physics*, **6** [3] 100–104 (1935).—If a solid is constructed of the same material and to scale with a body of any shape and subjected to initial and surface temperature conditions of the same character, properties can be derived to compare or contrast the temperatures at corresponding points in these solids. Seven properties are given in this paper, covering cases of variable and steady temperatures of solids with and without radiation or convection at any part of the boundary and with any fixed temperature distribution on the rest of the surface. The law used for the transfer of heat by radiation and convection is a very general one. The thermal coefficients are functions of the temperature. These properties are derived by substitutions of new variables into the heat equation and the boundary conditions. Some of the properties give important information about the effect of the size of a solid upon its rate of cooling or heating. All of the properties are useful in the determination of temperatures in any solid by measuring the temperatures in a large or small scale model.

Economic coal purchase. Chas. F. Wade. *Clay-craft*, **8** [5] 196 (1935).—The basis upon which coal is purchased for consumption in ceramic plants is an important factor if economic burning is to be accomplished. The most correct basis for coal selection is the proximate analysis by which the percentages of moisture, ash, fixed carbon, and volatile matter are determined. The apparatus used for burning the coal and the conditions for burning are dependent upon the nature of the coal, and the proximate analysis aids in determining these to the best vantage. M.C.S.

Electric furnaces in industrial heat treatment. I. A. G. Loblev. *Metallurgia*, **11** [63] 61–64 (Jan., 1935).—L. deals with various types of batch furnaces. **II.** *Ibid.*, **11** [65] 117–20 (March, 1935).—Continuous furnaces in which the charge is mechanically handled, types of furnaces including rotary annular-hearth, driven roller-hearth, conveyer-belt, pusher type, rotating drum, and continuous wire and strip are discussed.

(*B.B.N.F.M.R.A.*)

Electric kilns fired successfully. Charles W. Speirs. *Bull. Amer. Ceram. Soc.*, **14** [4] 156 (1935).

Electrical firing in the ceramic and glass industries. J. Courtois. *Céram., Verrerie, Émail.*, **2** [9] 391–94; [10] 441–43 (1934).—Electrical firing offers the advantages of cleanliness, easy and automatic control, even and rapid heating, and any desired kiln atmosphere. It is suitable for firing and glazing porcelain, etc. Electrical heating has found little application in glassmelting due to the contamination of the glass by resistors, but newer developments and suggestions are offered. M.H.B.

Manufacture of "colloidal" fuel. Stephen Wyndham. *Nature*, **135** [3405] 172 (1935).—Mechanical mixtures of coal and oil capable of retaining the coal particles in suspension for a time and at a temperature sufficient to enable its use in this form have been difficult to obtain. The respective specific gravities of coal and oil are 1.3 and 0.9. Additions of rosin, paraffin wax, and peptizing fluids have been used to keep the particles in suspension. Fair success was obtained but at a relatively high cost. The pulverizing of the coal to a particle size small enough for producing a stable emulsion was also expensive. W. has eliminated the costly process of dry-coal grinding by mixing the fine coal as received from the colliery with an equal amount of heavy oil and passing the mixture through a series of rolls until 99% passed a 200 I.M.M. mesh. The fineness and aëration obtained during the passage through the rolls produces a mixture which holds the coal particles in suspension for at least four months under normal working conditions. Coal less than $^3/_{16}$ in. in diameter is fed by a worm screw into the rotating mixture where it meets an oil spray to form the paste which is pumped to a pair of rolls 0.008 in. apart rotating in opposite directions at variable speeds of 3 to 1. It then goes to the second set which are 0.004 in. apart. Four to six sets are used, depending on the degree of fineness necessary to produce a stable emulsion. The initial cost of one 100-ton per week plant is approximately £1000. In burning the mixture under a steam boiler, it is preheated to about 250°F at a pressure of 15 to 20 lb./in.^{2} and air pressure is maintained at 2 lb. This gave a clear smokeless flame with no coking at the burner tip in tests at the Cardiff plant of Messrs. Wyndhams Liquid Coal Co., Ltd. J.L.G.

Purchase of coal. R. Wright. *Elec. Rev.*, **116** [2989] 342 (1935).—W. attacks the purchase of coal on the "as received" basis, citing the discrepancies that occur in the sampling, analysis, and testing of coals and the increased cost incurred for frequent sampling and testing. High-grade fuel, fuel of high calorific value and ash content below 6%, may not be the most efficient fuel for a particular condition. Five fuel grades are compared with comments on their characteristics. The larger the proportion of ash, the greater must be the handling and repair costs. J.L.G.

Reduction red in ceramic bodies. Berdel. *Ber. deut. keram. Ges.*, **15** [11] 558–60 (1934).—Studies of thin sections of ceramic bodies that showed red coloration disclosed the presence of orange-colored particles of no recognizable crystal form and no transparency or optical individuality in the conglomerate of silicates and quartz. The formation of a carbon suboxide, C_3O_2, which breaks down into CO_2 and C_2, the latter being reddish in color, is discussed. The red form of carbon is produced by holding reducing conditions for a long time at low temepratures;

at high temperatures the graphitic form is obtained. See also "Reddish—" *Ceram. Abs.*, **14** [5] 120 (1935). E.J.V.

Specific heats and dissociation of gases at high temperatures. KURT WOHL AND MICHAEL MAGAT. *Z. physik. Chem.*, **B19**, 117–38 (Oct., 1932).—The heat capacities of H_2O, H_2, O_2, and N_2 and the heat of the reaction $H_2O = {}^1/_2H_2 + OH$ were determined by the explosion method. The results for H_2O and H_2 are in good agreement with theoretical values, but those for O_2 and N_2 are somewhat low, because the duration of the explosion is so short that the molecules do not reach vibrational equilibrium. Heat capacities determined by this method are mean values over large temperature ranges. (*R.S.I.*)

PATENTS

Appliance for drying and firing refractory linings in tubes. GUTEHOFFNUNGSHÜTTE OBERHAUSEN A.-G. Ger. 593,412, July 25, 1932; *Keram. Rund.*, **42** [49] 613 (1934).—The appliance consists of a gas burner which projects into the interior of the tube. The head of the gas burner consists of a gas pipe tube that extends about over the length of the treated lining. A.K.

Brick and tile kilns. A. HABLA. Brit. 425,992, April 10, 1935 (Sept. 25, 1933), and Brit. 426,133, April 10, 1935 (Sept. 27, 1933).

Calcination of siliceous products. P. C. FASSOTTE. Brit. 426,157, April 10, 1935 (May 3, 1934).

Closure for tunnel kiln for firing salt-glazed pottery. KERAMISCHE INDUSTRIE-BEDARFS-A.-G. Ger. 601,004, Aug. 6, 1934. (*C.A.*)

Construction of kilns. UNIVERSAL GRINDING WHEEL CO., LTD., AND J. G. COWAN. Brit. 424,570, March 6, 1935 (Aug. 16, 1933).

Electric furnace and method of operating. R. C. BENNER, G. J. EASTER, AND C. E. HAWKE (Carborundum Co.). U. S. 1,997,622, April 16, 1935 (Nov. 17, 1931).

Tunnel kiln. HEINRICH KOPPERS G.M.B.H. (Joseph Daniels, inventor). Ger. 599,626, July 6, 1934. Addition to Ger. 573,854 (*Ceram. Abs.*, **13** [5] 129 (1934)). (*C.A.*)

Tunnel kilns or ovens. A. P. DENUS. Brit. 425,401, March 27, 1935 (June 14, 1932).

Geology

Clay occurrence at Buchtal. WALTER KIRCHER. *Ber. deut. keram. Ges.*, **15** [12] 625–32 (1934).—The ceramic properties of four kinds of clays found in an outcrop 400 m. wide and 1500 m. long near Buchtal are listed, showing the varied uses of the clays in this German deposit. E.J.V.

Demonstration of lateritic weathering and estimation of free alumina in the soil. I. PAUL PFEFFER. **II.** KURT UTESCHER. *Z. Pflanzenernähr., Düngung Bodenk.*, **33A**, 275–98 (1934).—The occurrence of free Al_2O_3 in soil, its importance as an indication of lateritic weathering, and methods for its detection are discussed. Experiments on the solubilities of various forms of hydrated Al_2O_3, minerals, and two laterites in boiling 1% NaOH and Tamm's oxalate solution are described. It is concluded that both attack unaltered silicates, but 1% NaOH is more suitable for the estimation of free Al_2O_3. Two or more 5-minute boilings with successive 250-ml. portions of 1% NaOH are sufficient to extract free Al_2O_3 from 5 g. soil or 2 g. laterite. Humus soils should first be carefully ignited. The presence of free hydrated SiO_2 decreases the solubility of Al_2O_3 in NaOH solution, so that the extraction from soil may not be quantitative. Free Al_2O_3 in soil is chiefly the result of lateritic weathering; from the products, concentrated HCl extracts less than 3 mol. SiO_2 to 1 of Al_2O_3, and dilute NaOH extracts less than 2 mol. SiO_2 to 1 of Al_2O_3. Normal processes of acidification in soils, even when carried to low p_H values, do not result in much decomposition of the SiO_2-Al_2O_3 complex. (*C.A.*)

Deposits of aluminum minerals in the two coasts of the Adriatic sea. CAMILLO CREMA. *Atti soc. ital. progresso sci.*, **22** [2] 120–44 (1934).—The most frequent Al mineral is bauxite: analysis of various samples gave (from Istria) Al_2O_3 52.25 to 63.13, Fe_2O_3 19.33 to 28.45, SiO_2 1.56 to 3.46, TiO_2 3.00 to 3.24, loss by heat 11.87 to 13.20; (from Dalmatia) Al_2O_3 49.22 to 61.11, Fe_2O_3 14.04 to 25.40, SiO_2 0.9 to 9.36, TiO_2 1.86 to 3.80, loss by heat 13.63 to 26.52; (from Central Apennines) Al_2O_3 51.78 to 57.60, Fe_2O_3 23.50 to 30.63, SiO_2 2.17 to 4.29, TiO_2 1.77 to 3.42, loss by heat 11.28 to 12.42; (from the Provinces of the Gargano Promontory) Al_2O_3 55.26 to 60.05, Fe_2O_3 20.19 to 23.12, SiO_2 2.22 to 3.24, TiO_2 2.10 to 2.35, loss by heat 14.25 to 17.80; (from Otranto Province) Al_2O_3 52.29 to 55.75, Fe_2O_3 22.97 to 30.64, SiO_2 2.97 to 4.86, TiO_2 1.81 to 3.07, loss by heat 8.60 to 16.46%. Geological descriptions of the deposits are added. (*C.A.*)

Feldspar in Australia. ANON. *Chem. Eng. Mining Rev.*, **27**, 133 (Jan., 1935).—Australian feldspar is low in Fe and obtainable in large, clean masses. Perthite is mined at Broken Hill, microcline at Londonderry, and albite at Ubini. There is a small import trade from Norway. H.H.S.

Geological relations of the Colditz kaolin and clay district. A. LAUBENHEIMER. *Ber. deut. keram. Ges.*, **15** [8] 437–44 (1934).—L. discusses the geological history and properties of the various clays and kaolins found around Colditz, Saxony. Illustrated. E.J.V.

German igneous rocks as raw material in the glass and ceramic industries. H. MOTSCHMANN AND E. MOTSCHMANN. *Z. prakt. geol.*, **40**, 172–76 (1932).—Thirty-one rock analyses and indications for the possible use of these rocks in the ceramic industry, principally as fluxes, are given. Included are greenstone, diabase, syenite, basalt, nephelite-syenite, porphyry-tuff, quartz-porphyry, granite-porphyry, felsite-porphyry, pitch-stone, nosean-phonolite, nephelite-phonolite, trachyte-phonolite, natrolite-phonolite, analcite-phonolite, basalt-lava, pumice, and trass. See also *Ceram. Abs.*, **11** [12] 635 (1932); **13** [4] 100 (1934). (*C.A.*)

German raw materials for the silicate industry. H. MOTSCHMANN AND E. MOTSCHMANN. *Keram. Rund.*, **42** [31] 379–82; [32] 395–97; [33] 409–10 (1934).—Bibliography. M.V.C.

Kaolin. III. Dehydration of kaolins and catalytic

influencing thereof. R. SCHWARZ AND K. NÜCHTER. *Ber. deut. keram. Ges.*, **15** [10] 514–17 (1934).—Results of studies of the rate of dehydration of kaolins to which has been added ammonium molybdate or sodium tungstate are discussed. These materials act as catalyzers in the dehydration of the clays. The chemical changes occurring during the process are described. For Part II see *Ceram. Abs.*, **12** [7] 279 (1933). E.J.V.

Petrography of crystalline formation of Bas-Limousin. J. JUNG AND M. ROQUES. *Compt. rend.*, **200** [9] 764–67 (1935).—A classification of the crystalline schists by zones and depths in the district of Périgueux, France, is given. M.H.

Petrology of Pennsylvanian shales and noncalcareous underclays associated with Illinois coals. II–III. RALPH E. GRIM. *Bull. Amer. Ceram. Soc.*, **14** [4] 129–34; [5] 170–76 (1935); for Part I see *Ceram. Abs.*, **14** [5] 125 (1935).

Properties of some Ohio red-firing clays. A. E. MACGEE, W. C. O. WHITE, AND T. A. KLINEFELTER. *Jour. Amer. Ceram. Soc.*, **18** [5] 155–62 (1935).

Research in feldspar preparation. G. GERTH AND H. ZIERGIEBEL. *Ber. deut. keram. Ges.*, **15** [10] 517–19 (1934).—Results of flotation experiments made to determine means of producing feldspar more free from mica and quartz are discussed. The effect of grain size on the results is pointed out. See also "Mica—" *Ceram. Abs.*, **14** [1] 25 (1935). E.J.V.

Titanium and zirconia in Australia. ANON. *Chem. Eng. Mining Rev.*, **27**, 183 (Jan., 1935).—The black sands of Byron Bay, N.S.W., are being treated for zircon and rutile. H.H.S.

BULLETINS

Geologic Atlas of the United States, folio 224, Somerset-Windber, Pa. G. B. RICHARDSON. 14 pp., 8 maps. Price 50¢. R. describes an area of 457 sq. miles lying chiefly in Somerset County, Pa., but including small parts of Westmoreland, Cambria, and Bedford counties. Maps show the topography, areal geology, economic geology, and geologic structure of the area. R.A.H.

Possibilities for the production of aluminum and magnesium from Washington ores. CARL F. FLOE. *State Coll. of Wash., Metallurgical Research Bur., Information Circ.*, No. 7, 5 pp. (1934).—Production of Al from clays is feasible and probably can be done at a cost that will compare favorably with the present cost of producing it by the Bayer process from bauxite. Mg can be recovered from magnesites and dolomites at a cost that should compare with the present cost of extracting it from salt brines. Production of Al and Mg uses large amounts of electrical energy. (*C.A.*)

Chemistry and Physics

Analysis of calcium fluoride. SANTIAGO ITURRIO ALZATE. *Quim. & Ind.*, **11** [150] 258–59 (1934).—A. gives a simplified method for analyzing products of varied composition. Results are satisfactory for industrial purposes. M.V.C.

Application of heat-of-wetting measurements to soil research problems. H. JANERT. *Jour. Agr. Sci.*, **24**, 136–50 (1934).—Experiments on the application of an improved method for determining heat of wetting are described. With pure single-base clays the heat of wetting represents a specific proportion of the heat of hydration of the adsorbed cations in their free state. A general correspondence between heat of wetting and base-exchange capacity in natural soils is shown; there is also under certain conditions a correlation with "heaviness" as measured by draw-bar pull. Wetting with organic liquids produces a heat effect which is proportional to the water heat of wetting for mineral soils. The dipole moment and the molecular volume of a liquid do not seem to determine completely the heat of wetting of a given soil in it. There is qualitative evidence that the quotient, water heat of wetting/organic liquid heat of wetting, is constant for mineral soils and regularly increases with progressive humus content. Changes of the physical conditions in the soils on the permanent experimental fields at Rothamsted and Woburn were clearly distinguished by application of the method. (*C.A.*)

Base exchangeability of clays and forming problems in ceramics (casting, turning, pressing). K. ENDELL, H. FENDIUS, AND U. HOFMANN. *Ber. deut. keram. Ges.*, **15** [12] 595–625 (1934).—Clear wet volume pictures of mixtures of the system clay–water are discussed with regard to the crystal lattice of clay minerals, the amount and type of exchangeable combined cation, and the free electrolyte in the surrounding solution. Based on the theoretical conception of Vageler of the law of mass action, the ideal colloid surfaces, and the theoretical conception of the Donnan balance, the process of clay liquefaction for ceramic casting processes was studied and tested with a new resistance viscosimeter. Using a new body tester, pressure-compression diagrams were obtained for ceramic clays and bentonite as well as for stoneware, porcelain, and steatite bodies made with them. The limits of satisfactory forming are set by a slight decrease in the water content. Formability and water content are dependent on the water solubility of the exchangeable bases or cations in the clay minerals present in the body. Next to the formability of pure clays, the determination of which is doubtful if based on the transition of ceramic kaolinites to bentonite, is the comprehensive conception of plasticity of ceramic bodies produced from these clays with added fluxing materials. The same formability can be obtained with entirely different quantities of plastic media. The wettability and bonding qualities of the clays used are possibly more important than the formability of the pure clays. The bondability of a plastic material is generally greater, the less material and the less water (in regard to the drying shrinkage) are needed in producing a plastic formable body. The organic colloids such as dextrin, sulfite liquor, and oils are next to Na-bentonite in bonding strength and distribution speed of water emulsions. Illustrated. E.J.V.

Ceric oxide as new opacifying agent. BYRON W. MERWIN. *Ceram. Ind.*, **24** [4] 214 (1935).—An investigation of the effect of ceric oxide in a high alkali borosilicate fritted glaze showed that (1) it corrects crazing; (2) it may be used as an opacifying agent in glazes but is not economical because large quantities must be used to get

the desired opacifying qualities. The oxide would be much easier to use as a source of ceric oxide than the sulfate, as the latter tends to flocculate the glaze due to the ease with which it breaks down, making the glaze difficult to apply. E.J.V.

Chemical investigation of ceramic raw materials and products. COMMITTEE FOR CERAMIC MATERIAL TESTING OF THE GERMAN CERAMIC SOCIETY. *Ber. deut. keram. Ges.*, **15** [12] 633–34 (1934).—Recommended methods for making chemical analyses on ceramic materials and products are given. E.J.V.

Chemical spectrum analysis, 1860 and 1935. W. GERLACH, E. RIEDEL, AND W. ROLLWAGEN. *Metallwirtschaft*, **14** [7] 125–32 (1935).—A history of the spectrum analysis, now 75 years old, is given. Present methods of industrial application and analyses of ores, rocks and minerals, and alloys are described. M.H.

Chemistry of colored glazes. WOLDEMAR WEYL. *Ber. deut. keram. Ges.*, **15** [7] 369–74 (1934).—The results of experiments on spectral absorption of colored glazes and solutions to determine the relationship of the color obtained to the composition of the base glazes or glasses are presented. Chemical, physical, and optical phenomena were studied. The effect of the concentration of the coloring oxide on the resultant color is also studied. E.J.V.

Chromate green analysis. C. P. A. KAPPELMEIER. *Verfkroniek*, **7**, 12–14, 35–36 (1934).—Chromate green (Prussian blue + chrome yellow) cannot be analyzed accurately by the method of Warnier (*ibid.*, **6**, 162, 187, 212 (1933)), because ferrocyanide is oxidized by chromate during the analysis. The following procedure overcomes this difficulty: Heat 0.3 to 0.4 g. of the dry powder for 20 to 30 min. on the hot plate with frequent stirring. Cool and boil with 20 cc. concentrated HCl and a little $KClO_3$ until dissolved. Evaporate to dryness and boil the residue with a mixture of 125 cc. 4 *N* NaOH and 25 cc. of 3% H_2O_2 for at least 0.5 hr., replacing evaporated water. Filter, wash the precipitate with 4 *N* NaOH, dissolve it in acid, and repeat the above treatment. Concentrate the alkaline filtrates to exactly 250 cc. and take 100 cc. for the iodometric determination of Cr and another 100 cc. for the determination of Pb as $PbCrO_4$. In the precipitate produced by NaOH determine Fe iodometrically. An alternate procedure is this: Treat 0.4 to 0.5 g. of pigment with 2 cc. alcohol and 10 cc. 4 *N* HCl. Evaporate to dryness and boil the residue with 125 cc. of 10% Na_2CO_3 solution replacing evaporated water. After 20 min., cool, neutralize to phenolphthalein with CO_2 gas, and filter off $PbCO_3$, $Cr(OH)_3$, and $Fe(OH)_3$. Determine these elements as above, after dissolving in dilute acid. Boil the filtrate with yellow HgO for 25 min., filter, and determine sulfate in this filtrate. Dissolve the Hg precipitate in hot 4 *N* HCl, oxidize with Br_2, and determine the ferricyanide iodometrically. (*C.A.*)

Collation of experimental data. XVI. A. ALISON. *Glass*, **11** [12] 477–78 (1934). **XVII.** *Ibid.*, **12** [1] 30 (1935).—A. discusses the development and use of the standard deviation or root mean square deviation as a means of representing and interpreting data. Examples and curves are included. **XVIII.** *Ibid.*, **12** [2] 58 (1935). A. describes various types of statistical analysis and discusses the value and adaptability of each. For Parts XIV–XV see *Ceram. Abs.*, **14** [2] 52 (1935). M.C.S.

Colorimetric method for the direct determination of sodium. O. M. SMITH AND HERBERT BLAIR. *Proc. Oklahoma Acad. Sci.*, **13**, 33–35 (1934).—The method of Caley and Foulk (*Ceram. Abs.*, **8** [12] 923–24 (1929)) was tested in a survey of about 140 samples of water after preliminary work on 48 other samples. The method is accurate to within about 0.35 mg. of Na. (*C.A.*)

Compressing strength of crystals. M. SCHULER AND A. DIMPKER. *Z. Instrumentenk.*, **55** [2] 63–70 (1935).—Testing methods for crystals to determine their compression strength are discussed, and results with spheres of sapphire, ruby, quartz, diamond, and steel when pressed against a plane surface of the same material are given. For a radius of the sphere below 0.2 mm., sapphires behaved better than steel under compression, while for larger diameters steel was more favorable. M.H.

Correction to the refractive indices of quartz in the infrared. D. G. DRUMMOND. *Nature*, **134** [3398] 937 (1934).—In the region 3 to 4 μ, the dispersion of crystalline quartz is about four times that of fluorite which makes its use as a prism desirable in this range since the dispersion more than makes up for loss due to absorption. Recent work with quartz and fluorite prisms showed that the values of Rubens for the indices of refraction of quartz in this range are in error. New values were estimated. These need checking by direct determination.

λ	n(Rubens)	n(corrected)	Difference
3.03μ	1.4987	1.4987	0.0000
3.18	1.4944	1.4947	0.0003
3.40	1.4879	1.4885	0.0006
3.63	1.4799	1.4809	0.0010
3.80	1.4740	1.4746	0.0006
3.87	1.4715	1.4715	0.0000

See also "Infra—," *Ceram. Abs.*, **14** [5] 126 (1935). J.L.G.

Determining small amounts of fluorine in enamels. W. DAWIHL. *Keram. Rund.*, **42** [49] 607–608 (1934).—The determination of small amounts of fluorine colorimetrically with the aid of titanium sulfate solution is rapid, practical, and reliable. With phosphoric acid and other troublesome impurities present, the fluorine is separated by the Williard and Winter distillation method. A.K.

Determining total surface of soils, clays, etc. VI. Influence of sodium carbonate additions upon the combination of water with hydrogen clay. H. KURON. *Z. Pflanzenernähr., Düngung Bodenk.*, **33A**, 298–305 (1934).—Experiments are described showing that the effect of Na_2CO_3 additions upon H clay is similar to that upon Ca clay. With an addition equivalent to the adsorption capacity, H_2O combination at low vapor pressure is a well-defined minimum. Treatment of clay with 0.05 *N* HCl does not reduce the adsorptive capacity. For Parts IV–V see *Ceram. Abs.*, **12** [8] 312 (1933). (*C.A.*)

Exact measurements of specific heats of solid substances at temperatures between 0 and 1625°C. I. F. M. JAEGER AND E. ROSENBOHM. *Rec. trav. chim.*, **47**, 513–57 (1928); for abstract see *Ceram. Abs.*, **7** [7] 494 (1928). **II. True specific heats of tungsten, rhodium, palladium, osmium, and iridium between 0 and 1625°.** *Rec. trav. chim.*, **51**, 1–46 (1932).—Numerical values up to 1700°C

are tabulated and formulas representing true specific heats are derived; comparisons with the behavior of Fe, Co, and Ni are drawn. **III. Systematic study of the causes of error due to the use of a metallic calorimeter and in measurements of previously worked metals.** F. M. JAEGER, E. ROSENBOHM, AND J. A. BOTTEMA. *Ibid.*, **52**, 61–84 (1933).—Attention is called to the fact that when measuring the specific heat of a metal the latter must eventually, by a suitable heat-treatment, be brought to a stable condition where the internal structure does not change any more during the measurement. **IV. Law of Neumann-Joule-Kopp-Reynault regarding the additivity of atomic heats of elements in their chemical combinations.** F. M. JAEGER AND J. A. BOTTEMA. *Ibid.*, **52**, 89–111 (1933).—Experimental proof is given that this law does not hold good and that the deviations, positive or negative, are a function of the temperature and generally increase with the latter. **V. Specific heats and thermal hysteresis of beryllium.** F. M. JAEGER AND E. ROSENBOHM. *Ibid.*, **53** [4] 451–63 (1934).—Crystalline metallic Be, when heated above 500 or 600°C, undergoes a remarkable and evidently reversible change of its internal condition which is shown by strong retardation of heat development of the hot metal on cooling; the original condition is not completely reached at room temperature even after 9 months. The X-ray spectrum shows some difference above 635°C. The physical properties of Be are strongly dependent on its preliminary thermal treatment and on the time elapsed since its cooling down from higher temperatures; no definite numerical value can be assigned to these properties. The presence of minute quantities of beryllium oxide almost completely prevents the abnormalities. The possible reasons for this behavior are discussed. For Part VI see *Ceram. Abs.*, **13** [10] 275 (1934). **VII. Calorimetric behavior of zirconium.** F. M. JAEGER AND W. A. VEENSTRA. *Ibid.*, **53** [7–8] 917–32 (1934).—Calorimetric measurements of different samples of pure Zr showed that the electric resistance increases with temperature up to 870°C and then diminishes with increasing temperatures until at 1157°C a minimum is reached; at still higher temperatures it increases again. On cooling, a pronounced hysteresis is observed, the resistance assuming its final value after a certain time. Heat radiation per cm.^{2} surface is, however, identical on heating and cooling. There exists a truly reversible transition, α-Zr $\rightleftarrows$ β-Zr; the α-modification has a close-packed hexagonal structure: $a_0 = 3.23$ Å, $c_0 = 5.14$ Å, density (15°C) = 6.52. The β-modification is cubic, with a body-centered cell, $a_0 = 3.61$ Å. Density is 6.39 at 870°C. The transition from α- to β-modification must take place rapidly as it also appears when the material is quenched. There are definite zones of heating in which no reproducible values of specific heat can be found and also where the increase of the latter with temperature is irregular. It is concluded that no complete state of internal equilibrium exists between 400 and 630°C. Specific heats ranged between 0.075 and 0.0869. The phenomena observed were similar to those found in Be, Ce, etc. M.H.

Methods of inducing crystallization. EDWARD W. WASHBURN. *Bull. Amer. Ceram. Soc.*, **14** [4] 138–41 (1935).

Physical and chemical principles involved in mixing iron ore and fluxes. I. J. KLÄRDING. *Arch. Eisenhüttenwesen*, **8**, 277–80 (1934).—Conditions involved in liberating iron oxide by mutual reactions of foreign oxides contained in the ore were studied. Best results were obtained for a ratio of $2CaO$ to $1SiO_2$. Lime and silica are bound chemically in calcium orthosilicate in such a manner that the reduction of iron oxide to metallic iron takes place without any interference. Conclusions are drawn regarding the phase diagrams of lime-silica and lime-silica-ferrous oxide. W.M.C.

Processes in the aging of ceramic masses. FELIX SINGER. *Kolloid-Z.*, **64**, 234–37 (1933).—A review with special reference to capillary processes is presented. (*C.A.*)

Rapid determination of alumina by the hydroxyquinoline method. KLASSE. *Ber. deut. keram. Ges.*, **15** [11] 560–71 (1934).—By modifying Robitschek's method it is possible to determine alumina accurately by the hydroxyquinoline method in about 2 hr. (including determination of iron), this being much better than by the usual ammonia precipitation method. The degree of accuracy in difficult cases amounts to $\pm 0.5\%$. Full details are given. E.J.V.

Rapid method for separating adsorbed calcium and magnesium from soil colloids. CH. BASILEIADOS. *Tech. Chronika* [Athens], **5**, 16–20 (1933).—Methods current in analysis of soils for Ca and Mg are discussed in detail and their relative merits compared, particularly those of Gedroiz and Hissink (Gedroiz, Chem. Bodenanalyse, p. 132, *Ceram. Abs.*, **6** [4] 159 (1927); Kappen, Die Bodenazidität, p. 161), with a proposed more rapid and thorough means of effecting separation of the Ca and Mg components in soil colloids. Comparison showed widely divergent results, *e.g.*, one soil gave values for Ca as 80 for Hissink's, 100 for B.'s, and negative results for Gedroiz's method. Determinations of CO_2 originating in inorganic carbonates also were compared. In B.'s method steam is introduced into a soil-NaCl mixture to effect exchange of cations. For samples of soils to which were added (1) no Ca or Mg, (2) 10% $CaCO_3$, and (3) 9% $CaCO_3$ and 1% $MgCO_3$, uniformly lower values were obtained by B.'s steaming method except in (3), wherein Hissink's method gave lower values for adsorbed Ca. This diminution is attributed partly to increased dilution of $MgCO_3$ with respect to $CaCO_3$, by reason of which there occurs a secondary reaction between the $MgCO_3$ in solution and $MgCl_2$. In dolomitic soils not all the Ca is determined by present methods because of fluctuations in the amounts of $MgCO_3$ present and the mechanical state in which they exist. The technique of B.'s method is as follows: Wash 10 g. of soil with alcohol at 80°, then on a filter twice with water. Transfer to a tall 400-cc. beaker containing about 100 cc. of hot *N* NaCl, and lead in steam through a 3-mm. glass tube which reaches to 5 mm. above the beaker bottom. Revolve the vessel slowly and allow steam to stir the mass vigorously for 35 min., avoiding loss by clamping an inverted funnel above the beaker. Regulate the rate of flow so that not more than 50 cc. of condensate is formed. When steaming is finished add 50 cc. of 2 *N* NaCl to take care of dilution, stir the mass well, and allow to cool. Transfer to a 250-cc. beaker with the aid of a stream of water containing 2 *N* NaCl, mix and filter. Dilute 50 cc.

of filtrate to 100 to 120 cc. with distilled water, treat with HCl, and analyze for Ca and Mg. In another 50 cc. of filtrate determine the carbonates by titrating with 0.01 *N* HCl or H_2SO_4, using Me orange (1 cc. 0.01 *N* acid is equivalent to 0.2 mg. Ca). The difference between the carbonate Ca thus determined and the total Ca is the adsorbed Ca. (*C.A.*)

Relation between the phenomenon of cation exchange with silica-alumina complexes and their crystal structure. J. B. VAN DER MEULEN. *Rec. trav. chim.*, **54** [1] 107–13 (1935).—The causes for base exchanges in clay soils were investigated; it seems that silicates which contain no Al or Al with a coördination value other than 4 do not show the cation exchange, while those silicates which contain Al atoms with the coördination value 4 clearly show the cation exchange. Further studies of this phenomenon are recommended. 30 references. M.H.

Relations of various physical, chemical, and technical properties of clays. K. ENDELL AND U. HOFMANN. *Ber. deut. keram. Ges.*, **15** [9] 480–84 (1934).—Discussing the results reported by Salmang and Kind (*Ceram. Abs.*, **14** [5] 127 (1935)), the authors give further details regarding analysis of the complex ions found in clays and the effect of the ammonium chloride base-exchange treatment on the complex ions. A study of the S-value and plasticity of the clays studied by the other investigators is reported. E.J.V.

Semiquantitative measurements of the solubility of quartz in supercritical steam. C. J. VAN NIEUWENBURG AND P. M. VAN ZON. *Rec. trav. chim.*, **54** [2] 129–32 (1935).—The solubility of quartz in superheated steam was determined at 380, 400, and 425°C and at pressures from 300 to 500 atmospheres by measuring the loss of weight of the mineral. Results are shown in curves. M.H.

Structure of kaolins from the viewpoint of the chemistry of ultramarine. I. Action of dealkalizing factors on sodium kaolinates. MIECZYSLAW DOMINIKIEWICZ. *Roczniki Chem.*, **12**, 836–53 (1932); *Bull. trav. dépt. chim. inst. hyg. état* [Warsaw], **45** (Series C) [2] 1–9 (1932).—$Na_6Al_6Si_6O_{24}$ (I) and $Na_{12}Al_8Si_6O_{27}$ (II) have been prepared from kaolin and Na_2CO_3. Thugutt's nepheline hydrate is identical with the trihydrate of (I). Na can not be removed from (I) by treatment with SO_2Cl_2, AcCl, Ac_2O, AcOH, S, NH_4Cl, SO_2, and H_2S at red heat; HCl at 175° converts it into $Na_4Al_6Si_6O_{23}$ (III). (II) is converted by SO_2Cl_2, AcCl, and Ac_2O into $Na_8Al_6Si_6O_{24}$, which yields (I) with S, NH_4Cl, or HCl at 110°, and this, as before, gives (III) on treatment with HCl at 175°, while the trihydrate of (I) yields that of (III) under similar conditions. The above results support the view that the basis of all aluminosilicates is hexa-aluminosilicic acid, and that this acid possesses three types of OH groups of different acidity. The existence of the compound $Na_2Al_6Si_6O_{22.5}$ described by Silber (*Ber.*, **14**, 941–46) is not confirmed. For Part II see *Ceram. Abs.*, **14** [3] 83 (1935). (*C.A.*)

Theory of thermal conduction. B. BRUZS. *Z. Physik*, **83**, 543–53 (1933).—A new principle in thermodynamics is suggested, according to which the properties of a system in a stationary state (such as a constant heat current) depend only on the properties of the system in thermal equilibrium. (*C.A.*)

Transformation of aluminum oxide from the beta to the alpha form. JOHN GALLUP. *Jour. Amer. Ceram. Soc.*, **18** [5] 144–48 (1935).

Tropical soils. III. The shrinkage behavior of lateritic and kaolinitic soils. F. HARDY. *Jour. Agr. Sci.*, **24**, 59–71 (1934).—Tropical red soils closely resemble kaolinitic materials in their shrinkage behavior and moisture relations, but are intermediate between this type and gray and yellow soils which display characteristic high total shrinkage, marked residual shrinkage, and high adsorptive capacity for moisture and cations. (*C.A.*)

Viscosity measurements in feldspar melts at high temperatures. WILLI M. COHN. *Ber. deut. keram. Ges.*, **15** [11] 551–58 (1934).—By use of the free falling ball method viscosity measurements at high temperatures were made simply. The distance the ball traveled in a definite period of time was measured after the melt had cooled to room temperature. The absolute viscosity was calculated by use of a modified form of Stokes' law. The advantage of this process as compared with the dynamic method is that each melt yields only one point on the viscosity-temperature curve. Results for some characteristic feldspar melts are given, with potash and soda contents extending over a great range. Observations on the effect of CaO, Fe_2O_3, and free silica on the viscosity are mentioned. Viscosity values for the same feldspar are discussed, those in the temperature range of 900 to 1200°C being obtained by Rieke and Mauve, and those in the range of 1300 to 1400°C by means of the free falling ball method. E.J.V.

Volumetric determination of potassium with methylene blue following precipitation as potassium picrate. A. BOLLIGER. *Jour. Biol. Chem.*, **107**, 229–34 (1934); abstracted in *Analyst*, **59**, 846 (1934). H.H.S.

X-ray fluorescence spectra for quantitative chemical analysis. N. D. BORISOV AND P. L. KIESELGOF. *Zhur. Fiz. Khim.*, **4**, 854 (1933); abstracted in *Chem. Zentr.*, **i**, 113 (1935).—A concise review as to the method of procedure is given. M.V.C.

BOOKS

Doctoral dissertations accepted by American Universities, 1933–1934. Number I. Edited by DONALD B. GILCHRIST. xvi + 88 pp. H. W. Wilson Co., New York, 1934. Price $1.00. Compiled for the National Research Council and the American Council of Learned Societies by the Association of Research Libraries. Publication of all doctoral dissertations accepted by American Universities during the year 1933–1934 in a single list was the objective of the Association of Research Libraries in planning this book. No list of similar scope has previously appeared for American dissertations. Two thousand six hundred thirty dissertations comprise the list. As it is now almost universal practice to file full manuscript theses in duplicate and to make copies available through interlibrary loan, the list fills a real and growing need to libraries. The preliminary chapter gives an extensive record of previous thesis lists, annual lists of doctoral dissertations in progress, university publications abstracting dissertations currently, statistical tables showing doctorates in science according to subject, 1925–1934, and distribution of doctorates for 1933–1934 by university by

subject. There is also a table showing the present practice in all universities whose theses are listed as to the publication and loaning of their own dissertations.

Electrolytes. HANS FALKENHAGEN. Translated by R. P. Bell. International Series of Monographs on Physics. xvi + 348 pp. Oxford Univ. Press, London, 1934. Price 25s net. Briefly reviewed in *Nature*, **135** [3411] 416 (1935).—F. gives a thorough treatment of the subject from Faraday to recent applications of quantum mechanics to electrode processes. J.L.G.

Electronic structure and properties of matter. C. H. DOUGLAS CLARK. xxv + 374 pp. John Wiley and Sons, New York, 1934. Price $5.50. This is the first volume of "a comprehensive treatise of atomic and molecular structure." In the first part of this volume is given a brief, non-mathematical account of practically every theory of atomic structure ever proposed, without any clue to respective merits and failings. The rest of the space is devoted to the various theories of the physical properties of matter. The bibliography is extensive. (*R.S.I.*)

Introduction to optical investigation with the polarizing microscope (Anleitung zu optischen Untersuchungen mit dem Polarisations-mikroskop). F. RINNE AND M. BEREK. viii + 279 pp. Max Janecke, Leipzig, 1934. Price 11.60 gold marks. Briefly reviewed in *Nature*, **135** [3405] 167 (1935).—The book reviews the applications of microscopy to the qualitative identification of crystals and to the quantitative determination of crystalline mixtures. Sections on luminescence and on the application of the microphotometer for the measurements of absorption are included among those describing recent developments in the field of microscopy. Illustrated with diagrams and photographs. J.L.G.

Mineral physics studies. R. S. DEAN *et al.* *Metallurgical Div. Prog. Rept.*, No. 10; *Bur. Mines Rept. of Invest.*, No. 3268, 107 pp. This report embodies papers on applied mineral physics, including explosive shattering, electrical properties of mineral aggregates, apparatus for determining the magnetic constants of mineral powders, magnetization curves for magnetic powders, coercive force, magnetic properties of mineral powders, and practical aspects of alternating magnetic separation. See also *Ceram. Abs.*, **13** [6] 161 (1934). R.A.H.

Mysteries of the atom. H. A. WILSON. viii + 146 pp. Chapman and Hall, London, 1934. Price 10s 6d net. Briefly reviewed in *Nature*, **134** [3397] 895 (1934).—W. clearly explains new facts and new ideas in physical science. J.L.G.

PATENTS

Lithium silicon composition. HANS OSBORG (Maywood Chemical Works). U. S. 1,997,340, April 9, 1935 (July 8, 1930; July 28, 1932). A high-temperature lithium-silicon composition is composed of lithium and silicon and substantially free from decomposition even at temperatures of the order of 700°C and under inert atmospheres; a high-temperature lithium-silicon composition of this character contains nickel silicide.

Manufacture of rutile. JOACHIM ROCKSTROH, FRIEDRICH RASPE, AND HEINRICH KIRCHER (I. G. Farbenindustrie A.-G.). U. S. 1,995,580, March 26, 1935 (April 7, 1934). The process of preparing rutile from anatase consists in performing the transformation in the presence of substances crystallizing in the rutile lattice but being chemically different therefrom.

Method of decomposing and further treating material containing titanium oxide. S. S. SVENDSEN (C. F. Burgess Laboratories, Inc.). U. S. 1,995,334, March 26, 1935 (June 4, 1932).

Production of aluminium fluoride. BRITISH ALUMINIUM CO., LTD., W. E. SIMS, S. F. DERBYSHIRE, AND E. J. BLOORE. Brit. 425,693, April 3, 1935 (Sept. 20, 1933).

General

Ceramics and the chemical industry. G. N. HODSON. *Brit. Clayworker*, **43** [514] 323–26 (1935).—Under "uses of clay," H. describes historical uses and classifies present day uses arbitrarily into (1) building materials, (2) refractory materials, and (3) chemical stoneware and porcelain. The first two classifications are briefly discussed, but the third class is treated in detail. The manufacture of stoneware, physical properties, resistance to heat changes, and many uses of stoneware are discussed in detail. R.A.H.

Clays containing quartz and mica. K. ENDELL, U. HOFMANN, AND D. WILM. *Sprechsaal*, **67** [20] 293–95; [21] 309–11; [22] 325–28 (1934).—The present state of the colloid-chemical and X-ray studies of ceramic clays is reviewed; 11 clays containing quartz and mica were investigated according to these and other ceramic methods. The effect of the fineness of quartz on the X-ray interferences was studied. Continuous interference rings first show quartz $< 2\mu$. The differences in the fineness of quartz in the clays studied was considerable. The assumption of Zwetsch ("X-ray—," *Ceram. Abs.*, **13** [11] 304 (1934)) that mica is best studied by means of X-rays in samples heated to 600° was confirmed. This testing is also suitable for determining the various sizes of quartz. The action of mica on lowering or removing the cristobalite effect in kaolins and clays fired to 1400° was confirmed in special tests. In the case of Grossalmeroder clay (for glasspots) the cristobalite effect of the 50% quartz present was removed by 15% mica. The lowering or removing of the cristobalite effect by mica in the expansion curves is made clear by systematic X-ray studies. The following points are important for ceramic practice: (*a*) There is a relationship between the fineness of quartz and mica content of ceramic clays with the cristobalite effect and the stresses produced in fired bodies or in glazes. (*b*) Coarse particles (preventing a faultless manufacture) in paper kaolin heated to 600° can be identified by X-rays. (*c*) An appropriate new division of ceramic clays is necessary. See also *ibid.*, **13** [4] 101 (1934). M.V.C.

Glazes from waste materials and low-grade raw materials. FRITZ RINCKE. *Keram. Rund.*, **42** [49] 608–10 (1934).—R. gives analyses of raw and waste materials together with calculations of batch compositions for various types of glazes which have been made wholly or in part from very impure clay or waste material such as cullet. A.K.

Silicosis: Effects of dust on the lungs. K. R. MOORE. *Chem. Eng. Mining Rev.*, **27**, 122–25 (Jan., 1935). H.H.S.

Vicat apparatus for the comparative determination of moisture in ceramic mixes. A. SIKORA. *Keram. i Steklo*, **11** [1] 30–31 (1935).—Details of experiments in using the Vicat apparatus to determine the moisture of various ceramic mixes are given. Diagrams are plotted. M.V.C.

BOOK

Laboratory: its place in the modern world. D. STARK MURRAY. The Fen Series, No. 8. 117 pp. Fenland Press, 1934. Price, paper 2s net; cloth 3s net. Reviewed in *Nature*, **134** [3397] 889 (1934).—M. explains the functions of the laboratory and the services it renders to industry and to the State. J.L.G.

PATENTS

Method of maturing ceramic articles and apparatus therefor. R. C. BENNER, A. L. BALL, AND H. R. HOUCHINS (Carborundum Co.). U. S. 1,996,851, April 9, 1935 (Sept. 3, 1932). The steps in the process of curing a ceramic article comprise heating a formed ceramic mass in a mold to the temperature of vitrification of a portion of the mass, and repeatedly increasing and decreasing alternately the pressure of the atmosphere to which the article is exposed during heating.

FOR A COMPLETE LIST OF THE JOURNALS RECEIVED IN THE OFFICE OF *CERAMIC ABSTRACTS* SEE OUTSIDE BACK COVER

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Abrasive Industry
American Enameler
American Glass Review
American Refractories Institute Technical Bulletin
Arhiv za Hemiju i Farmaciju
Berichte der Deutschen Keramischen Gesellschaft
Better Enameling
Bibliographia Italiana
Brick & Clay Record
British Clayworker
Bulletin of the American Society for Testing Materials
Bulletin of the British Non-Ferrous Metals Research Assn.
Canadian Chemistry and Metallurgy
Centro di Studi Ceramici
Ceramic Age
Ceramic Forum
Ceramic Industry
Céramique
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Chemist
Chemistry and Industry
Chimica e Industria
Claycraft
Clay Products News
Corriere dei Ceramisti
Crockery & Glass Journal
Dependable Highways
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Giornale di Chimica Industriale ed Applicata
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Glass
Glass Industry
Glastechnische Berichte
Grits and Grinds
Industrial and Engineering Chemistry
Industrial Heating
Industrial Standardization
Industrie dei Silicati
Journal of the Canadian Ceramic Society
Journal of the Indian Ceramic Society
Journal of the Institute of Metals
Journal of the Iron and Steel Institute
Journal of Research of the National Bureau of Standards
Journal of the Society of Chemical Industry, Japan
Journal of the Society of Glass Technology
Journal of the Western Society of Engineers
Keramika i Steklo
Keramos
Metal Progress
National Glass Budget
Official Gazette of the U. S. Patent Office
Official Journal (British Patents)
Ohio State University Engineering Experiment Station News and Bulletin
Physics
Pottery Gazette
Quimica e Industria
Referatkartei der Silikatliteratur
Refractories Journal
Rensselaer Polytechnic Institute Bulletin
Revue de matériaux de construction et de travaux publics
Review of Scientific Instruments
Ricerca Scientifica
Rock Products
Sands, Clays, and Minerals
Scientific Monthly
Sprechsaal
Stahl und Eisen
Tegel
Tonindustrie-Zeitung
Transactions of the American Foundrymen's Association
Transactions of the Ceramic Research Institute (Leningrad)
Transactions of the Ceramic Society (English)
Transactions of the Optical Institute (Leningrad)
Ukrainian Chemical Journal
Verre et Silicates Industriels
Zeitschrift für praktische Geologie
Zprávy Československé keramické společnosti